ATTENTIONAL BEHAVIORS IN INFANCY PREDICT ATTENTIONAL AND EXECUTIVE CONTROL BETWEEN 30 AND 42 MONTHS OF AGE

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A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Psychology and Neuroscience

Chapel Hill
2016

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ABSTRACT

Rebecca L. Stephens: Attentional Behaviors in Infancy as Predict Attentional and Executive Control Between 30 and 42 Months of Age
(under the direction of J. Steven Reznick)

Developmental researchers seek to understand the processes that contribute to the changes that occur throughout the lifespan. During infancy, toddlerhood, and early childhood, these processes are integral for healthy cognitive development. In the first year of life, one behavior that is commonly observed and measured is attention, and research has established the importance of early attentional behaviors in the development of later cognitive abilities. The First Year Inventory (FYI) was designed to identify 12-month olds at risk for an eventual diagnosis of autism spectrum disorder (ASD). Preliminary research created three attention-based constructs (responding to attention coordination, initiating attention coordination, and sensory and attentional engagement) derived from the FYI items as a novel way to use this measure in developmental research. The current study was designed to examine the predictive value of these three attention constructs in regards to patterns of the development of attentional and executive control between 30 and 42 months of age. Four subgroups were identified on the basis of individual differences in both the 30-month scores and the rate of change between 30 and 42 months. These subgroups represented distinct developmental trajectories, and group placement was predicted by 12-month attentional behaviors. The relation between parent-reported 12-month attention and 42-month executive function was explored, analyzing the moderating effect of attentional control subgroup. Findings suggest that the pattern of development between 30 and 42 months affects the strength of the relation between early attentional behaviors and aspects of executive function in early childhood. Lastly, parent-reported executive function behaviors were compared to laboratory assessments of the same constructs. Although analyses revealed little to no relation between these distinct measurements, the lack of findings points to potential concerns regarding methodology commonly used to measure these cognitive constructs in early childhood. Overall, these findings help to fill a gap in our understanding of early childhood cognitive development and illustrate the value of examining individual trajectories, as opposed to one or more independent time points.

ACKNOWLEDGEMENTS

First and foremost, to my family: You have all supported me through all of the ups and downs. You are a consistent and unconditional support system, and I don't thank you enough.

To Jonathan: Thank you for standing patiently by my side through this entire process. You deserve a medal. You are my person and one of the main reasons I am here today.

To the Reznick lab undergraduate research assistants: This project would never have happened without your help and dedication. A special shout-out to Laura, Lizzie, Emma, and Mary Katherine who have been on the team since the beginning.

To my entire dissertation committee: Thank you for your constant support, feedback, and patience. Each of you has played a distinct role in my graduate education, and I am lucky to have had the opportunity to learn from you.

To Barbara: Thank you for always being available to talk. You've helped me through some extremely difficult times, and you're just so good at helping keep things in perspective.

To Peter: Thank you for all of the times you let me sit in your office and cry. You've stepped in every time I've needed someone, and you've had my back every step of the way. I can't thank you enough for the overwhelming support you've provided, especially during these last few months.

To Steve: Thank you for all of your support, guidance, and constant reassurance. It's been a bumpy ride, but we're here. I feel so lucky to have been mentored by you, and I will always be thankful for the incredible advice, wisdom, and basketball knowledge you've passed along. I am beyond honored to be your "grand finale." Go Heels!

TABLE OF CONTENTS

LIST OF TABLES ix

LIST OF FIGURES x

LIST OF ABBREVIATIONS xi

Chapter 1: Introduction 1

  Background & Significance 1

    Infant Attention/Joint Attention 1

    Executive Function 6

    Patterns of Development in Other Domains 13

  Preliminary Research 16

  The Present Study 18

  Specific Aims 19

Chapter 2. General Methods 21

  Participants 21

  Measures and Procedures – Preliminary Research 25

  Procedure – 42-month wave 29

  Data Analysis 35

Chapter 3. Specific Aim 1 38

  Specific Methods 38

Results 39

Specific Aim 1 Discussion 56

Chapter 4. Specific Aim 2 58

Specific Methods 58

Results 59

Specific Aim 2 Discussion 67

Chapter 5. Specific Aim 3 70

Specific Methods 70

Results 71

Specific Aim 3 Discussion 74

Chapter 7. General Discussion 76

Developmental Considerations 79

Neurological Considerations 80

Psychopathological Considerations 83

Study Limitations 85

Future Directions 87

Conclusions 88

APPENDIX 89

REFERENCES 92

LIST OF TABLES

Table 1. Complete participant demographics 24

Table 2. Correlations between BDQ and ECBQ attention subscales (30-month scores reported) 29

Table 3. Laboratory task completion 33

Table 4. Number of participants with full data for each survey 34

Table 1.1. Comparison of models predicting 30- and 42-month outcomes from 12-month FYI attention scores 41

Table 1.2. Regression models predicting change scores from FYI attention scores (all values controlling for 30-month scores). 42

Table 1.3. Change score statistics 43

Table 1.4. Group sizes for change comparison analyses 45

Table 1.5 Differences in FYI attention scores across four change groups 49

Table 2.1 Simple linear regression analyses predicting BRIEF-P scores from FYI attention constructs 60

Table 2.2. Moderation model results for BRIEF-P indices as outcomes. *F*-values for interaction terms reported 62

Table 2.3. Group sizes for individual group regression analyses. 63

Table 2.4. Regression models for BDQ attentional control groups (FYI attention composite predictor) 64

Table 2.5. Regression models for ECBQ/CBQ Impulsivity groups 66

Table 3.1 Correlations between 42-month laboratory tasks and 42-month BRIEF-P scores 72

Table 3.2 Correlations between 30-month laboratory tasks and 42-month EF scores 73

Table 3.3 Correlations between 30- and 42-month laboratory tasks 73

LIST OF FIGURES

Figure 1. From Mundy et al. (2009) illustrating the transitional learning period in the first two years of life 6

Figure 1.2. Four patterns of change in attentional control (mean scores plotted) 46

Figure 1.3. Four patterns of change in impulsivity (mean scores plotted) 47

Figure 1.4. Attentional control group means of FYI attention mean score 50

Figure 1.5. Focused Attention group means of FYI attention mean score 51

Figure 1.6. Social Engagement group means of FYI attention mean score 52

Figure 1.7. Attentional Focusing group means of FYI attention mean score 53

Figure 1.8. Impulsivity group means of FYI attention mean score 54

Figure 1.9. SRS group means of FYI attention mean score 55

Figure 2.1. Relation between 12-month FYI Attention composite and 42-month Global Executive Composite 60

Figure 2.2. Relation between 12-month FYI attention composite and 42-month Global Executive Composite across different BDQ attentional control groups 65

Figure 2.3. Relation between 12-month FYI Attention composite and 42-month Global Executive Composite across different ECBQ/BDQ Impulsivity groups 67

LIST OF ABBREVIATIONS

ASD	autism spectrum disorder
BDQ	Behavioral Dimensions Questionnaire
BRIEF-P	Behavior Rating Inventory of Executive Function – Preschool Version
CBQ	Childhood Behavior Questionnaire
DCCS	Dimension Change Card Sort
ECBQ	Early Childhood Behavior Questionnaire
EDP	Early Development Project
EF	executive function
EMI	emergent metacognition index (from the BRIEF-P)
FI	flexibility index (from the BRIEF-P)
GEC	global executive composite (from the BRIEF-P)
IAC	initiating attention coordination
IJA	initiating joint attention
ISCI	inhibitory self-control index (from the BRIEF-P)
RAC	responding to attention coordination
RJA	responding to joint attention
RI	response inhibition
SAE	sensory and attentional engagement
SRS-2.0	Social Responsiveness Scale, Second Edition
SS	set shifting
WM	working memory

Chapter 1: Introduction

Background & Significance

Current research in infant and toddler development is often based on identifying behaviors that differentiate typical and atypical trajectories of development. There has been a surge in interest stemming from researchers, funding agencies, and the media in the causes and symptoms of neurodevelopmental disorders, pushing especially for multidisciplinary approaches to research. This has resulted in an increased emphasis on identifying behaviors during infancy that predict subsequent problematic cognitive development. One of the behaviors that has been studied in infants from very young ages is attention. Research suggests that early attentional behaviors such as looking time and joint attention are predictive of a number of later cognitive abilities (Colombo, Kannass, Walker, & Brez, 2012; Mundy, Sullivan, & Mastergeorge, 2009).

Infant Attention/Joint Attention

In early infancy, the most commonly used indicator of attention is looking time, or how long an infant fixates on a particular stimulus. Many techniques for studying cognitive, sensory and perceptual constructs involve measures of looking time. For example, paradigms such as habituation and familiarization have been used in infants as young as a few days old and allow researchers to make inferences about cognitive processing in terms of how much attention is paid to a particular stimulus (e.g., Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni, Csibra, Simion, & Johnson, 2002). As infants' visual systems continue to develop, the stimuli used in these paradigms become increasingly complex. Neonates are unable to visually process anything much more complicated than simple geometric shapes or faces, but as they mature, infants become able to process stimuli that include different colors, shapes, movement, and even multimodal components.

Infant looking behaviors display dramatic changes over the first year of life (see, for example, Courage, Reynolds, & Richards, 2006). Although there are individual differences in how infants perceive and process particular stimuli, research has established a consistent trajectory of the duration of looking time during the first year. Between birth and about 3 ½ months, infants increase looking time to stimuli as a result of the continuing maturation of the visual system and the enhanced ability to obtain and process greater amounts of information. Between 3 ½ and 6 months, there is a steady decline in the duration of looking time that is attributed to the improved efficiency of the perceptual system, as more mature infants do not require as much time to scan and process stimuli as do less mature ones (Colombo, 2001, 2002; Colombo & Mitchell, 1990).

Beyond six months, looking time varies based on the complexity of the stimulus, with more salient, dynamic, and patterned stimuli eliciting longer looking times than static, geometric shapes. By this point the visual system is considered to be close to functionally mature, so increased looking time to more complex stimuli is thought to reflect the infant's ability to obtain and process greater amounts of information (Colombo et al., 2004; Courage et al., 2006; Richards, 2010).

Although looking time has long been a preferred measure of infant attention, there are likely a number of cognitive processes contributing to looking behavior, beyond attention. Research using physiological techniques has in fact determined that across a period of looking time, a variety of mental processes are occurring, including, but not limited to, initial alerting, fixed attention, and encoding (see Colombo, 2001; Colombo & Mitchell, 2009, for an in-depth analysis of these processes). Further, there is a wide range of operational definitions of attention, suggesting that multiple processes are involved and that any measure of "attention" must clearly delineate what process is being measured. The heterogeneous nature of attention thus complicates the interpretation of findings obtained looking time is used as an outcome measure. As such, researchers need to make a number of assumptions and consider the limitations of what can be understood about infant cognition from these measures.

According to Colombo and colleagues (2001, 2002, 2012), attention includes four distinct categories. The first state, the "attentional state" is described as "a neutrally based organismic state that raises the probability of learning" (Colombo et al., 2012, p. 24). Although it is difficult to directly link infant looking time to later cognitive outcomes, research maintains that attention plays a major role in facilitating learning by preparing and coordinating the systems involved in receiving and engaging with environmental stimuli. Further, once attention is controlled voluntarily, looking behaviors are more predictive of working memory, rule-based learning, planning, and additional cognitive abilities (see Colombo et al., 2012 for a more detailed overview).

In addition to looking time, research has focused on infants' abilities to disengage from visual stimuli or to shift attention. In the 1960s and 1970s, researchers explored a behavior they called "obligatory looking," occurring in infancy between birth and around two months of age: infants were unable to disengage from a stimulus (Stechler & Latz, 1966). This behavior was described later as "sticky fixation" (Hood, 1995) and has been studied extensively over the past few decades (Colombo, Richman, Shaddy, Follmer Greenhoot, & Maikranz, 2001; Hopkins & van Wulfften Palthe, 1985; Hunnius & Geuze, 2004). With further brain development, infants lose the propensity to become "stuck" on a particular stimulus and are better able to shift attention more reliably and with shorter latencies (Hood & Atkinson, 1993; Johnson, Posner, & Rothbart, 1991).

This ability to shift attention between stimuli is directly related to the early development of joint attention behaviors. Joint attention involves the coordination of engagement between two individuals to focus on a third entity (object, other person or event). Significant research has established the onset of joint attention to be before the age of 12 months, but questions remain as to when exactly these skills emerge and can be reliably measured, as well as the meaning of individual differences in the onset and the frequency of the observable behaviors.

Responding to joint attention (RJA) refers to a person's ability to follow the direction of the gaze and/or gestures of others in order to share a common point of reference (Mundy & Newell, 2007). Researchers debate about the earliest time at which an infant is capable of responding to joint attention bids; some research indicates that RJA can be seen as early as 3 months (D'Entremont, Hains, & Muir, 1997; Hood, Willen, & Driver, 1998), whereas other researchers argue that early gaze following does not require the same level of social understanding and thus does not constitute joint attention. Joint attention implies that there is some understanding of intent between social partners. That is, an infant who responds to joint attention bids is thought to realize that the initiator means to communicate something through that bid. Gaze following, on the other hand, may only be a reflexive or perceptual response to a shift in another's gaze without any understanding of intent (Bedford et al., 2012). Further, gaze following does not necessarily involve a shift to a particular point of reference, and therefore fails to meet the triadic criterion of joint attention. Gaze following is, however, a necessary component to RJA. Infants are initially capable of engaging in RJA behaviors between the ages of 6 and 10 months, and variability can be detected between infants as early as 8 or 9 months, with these individual differences extending through the preschool period.

Around 9 to 12 months, there is a shift in typically-developing infants' joint attention capabilities, with infants becoming more consistent and accurate in responding to bids for joint attention. This is also the age range during which initiating joint attention (IJA) behaviors emerge. IJA bids occur when infants exhibit the use "of gestures and eye contact to direct others' attention to objects, to events, and to themselves" (Mundy & Newell, 2007, p. 269).

As with RJA, IJA has been linked to a variety of social and cognitive constructs in toddlerhood and early childhood. Because IJA requires that an infant spontaneously engage with another person to share an experience, researchers have explored whether and how IJA behaviors predict social competency in both typically- and atypically-developing children (e.g., Schietecatte, Roeyers, & Warreyn, 2012).

One approach to considering the relation between joint attention and later cognitive abilities is through the construct of Theory of Mind (ToM). This construct has been researched extensively in the typical and atypical developmental literature, and is known to have ties to a number of social and cognitive constructs, including joint attention (Baron-Cohen, Tager-Flusberg, & Cohen, 1994; Charman et al., 2000; Happé, 1993; Tomasello, 1995). Theory of Mind refers to the ability of a child to ascribe mental states to oneself and to others, and to understand that one's own mental states (thoughts, intentions, beliefs, etc.) may differ from those of others. This ability requires that a child mentally represent his or herself and another person as separate people with separate mental states. Further, the child must be able to shift between his or her state and that of someone else to understand different perspectives. These factors are directly related to the mental abilities required for the development of many higher-order cognitive processes.

Figure 1 below describes a proposed relationship between joint attention and Theory of Mind (Mundy et al., 2009). In this model, joint attention sets the stage for a learning period during which children make significant gains in a wide range of cognitive abilities, stemming from greater understandings of the intentions of others. One particular set of these higher-order cognitive abilities that has been tied directly to Theory of Mind is *executive function* (Carlson, Mandell, & Williams, 2004; Hughes, 1998; Hughes & Ensor, 2005, 2007; Müller, Zelazo, & Imrisek, 2005; Müller et al., 2012; Ozonoff, Pennington, & Rogers, 1991; Perner & Lang, 2000).

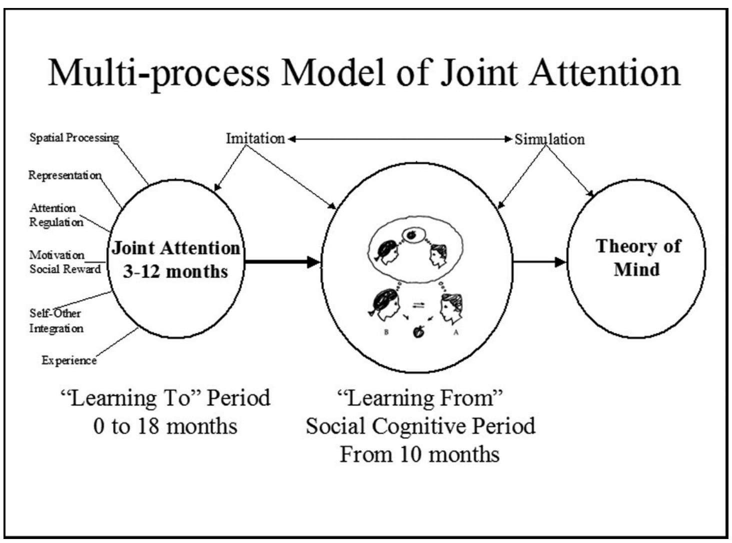

Figure 1. From Mundy et al. (2009) illustrating the transitional learning period in the first two years of life

Executive Function

The overarching construct of executive function (EF) has been broadly defined as goal-directed behaviors that allow an individual to override automatic responses (Garon, Bryson, &

Smith, 2008), control processes that regulate thoughts and behaviors (Miyake & Friedman, 2012), self-regulatory mental processes (Wiebe, Sheffield, Nelson, Clark, Chevalier, & Espy, 2011), or the higher-order cognitive processes that underlie goal-directed behavior (Hughes & Ensor, 2005). Although the operational definitions of executive function vary, the consensus is that it represents higher-order cognitive processing and is controlled by frontal areas of the brain and neural networks that inhibit automatic responses for efficiently executing a goal-directed action or task (Miller & Cohen, 2001).

The most prominent framework of executive function divides the construct into three distinct components or factors: working memory, response inhibition, and set shifting (Miyake et al., 2000). Significant research has confirmed these factors both in older children and adults (Fisk & Sharp, 2004; Friedman et al., 2008; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003). Although this framework has been applied to young children (Garon et al., 2008), and studies have confirmed factor loading of executive function measures on these constructs (e.g., Müller, Liebermann-Finestone, Carpendale, Hammond, & Bibok, 2012a), other factor structures have been proposed for toddlerhood and early childhood. Further complicating the research on EF is the lack of a truly developmental understanding of the nature and early trajectory of these skills. Researchers have examined EF abilities during early childhood (i.e., ages two through five), school years, and into adulthood but remain in the dark about the processes underlying the developmental gains in EF.

At its most basic level, *working memory* (WM) refers to the ability to hold and manipulate information over varying periods of time, without the assistance of external or physical cues (Alloway, Gathercole, Willis, & Adams, 2004; Baddeley & Hitch, 1974; Goldman-Rakic, 1987). As such, WM requires mentally representing an object or idea in the face of distractions. Although basic WM paradigms have been used with infants as young as 6 months (Reznick, Morrow, Goldman, & Snyder, 2004), as children age, the tasks used to assess WM need to become increasingly complex to capture the growth in WM skills (regarding how much information can be held and manipulated or how long of a delay the infant can tolerate before acting).

By six months of age, infants are able to hold a representation in mind over a delay of one to two seconds (Reznick et al., 2004), and by well into the second year and beyond, toddlers have acquired the ability to update and manipulate information (Alloway et al., 2004). However, although we are familiar with many of the mechanisms underlying WM in infancy, a lack of research measures more complex working memory abilities in children under the age of 3. This limited understanding stems from the need for tasks that accurately target these skills, a scarcity of longitudinal data, and inherent difficulties of any research done with toddlers or preschoolers (Garon et al., 2008). Thus, we still lack a solid grasp on the developmental trajectory of simple and complex working memory from infancy through early childhood.

Working memory abilities are considered to develop alongside the executive attention network of the brain, as the prefrontal cortex takes over the roles of attentional control, and research directly links WM with prefrontal cortex activity (e.g., Kwon, Reiss, & Menon, 2002; Scherf, Sweeney, & Luna, 2006). The majority of neuroimaging research, however, has been done on older children and adults, so although a neural picture of improvement across this age range is valuable, there remains a gap in research on the direct neurological underpinnings of WM during infancy, toddlerhood and early childhood.

Response inhibition (RI), considered to be the second aspect of EF to develop, requires the withholding or restraint of a dominant response. The majority of RI tasks also require WM, such as to remember a rule that exerts control over behavior. The earliest form of RI is considered to be the ceasing of an enjoyable behavior for a specific rule-based purpose, a construct that has been studied extensively using delay of gratification paradigms (e.g., Kochanska & Aksan, 1995; Mischel, Ebbesen, & Zeiss, 1973). These delay tasks can be distinguished from more complex RI tasks that involve a conflict between a required and a prepotent response (Carlson & Moses, 2001). Children's performance on such complex tasks varies based on the prepotency of the dominant response, such as in a "Simon Says" game, which requires inhibition of an action that the child is directly being instructed to perform (Murray & Kochanska, 2002).

The third factor in widely accepted models of EF is *set shifting* (SS), which is the ability to shift between mental states, sets, or tasks (Miyake et al., 2000). Set shifting tasks involve two phases: forming a mental set in which there is an association between a stimulus and a response; and switching to a new mental set that in some way conflicts with the first (Garon et al., 2008). Research shows that set shifting requires previously existing working memory and inhibition abilities (Best & Miller, 2010; Garon et al., 2008). Before children are able to shift between two distinct "sets," they must be able to maintain the set (WM) and inhibit the first association (RI) in order to activate a second (Best & Miller, 2010).

Although the previously discussed factor structure of executive function is perhaps more commonly studied than other models, especially in older children and adults, many additional models exist to explain the structure and purpose of executive function in early childhood. For example, some researchers argue that executive function in this age range represents a single executive control factor that spans multiple domains (Wiebe, Espy, & Charak, 2008; Wiebe et al., 2011). Another theory asserts that executive function is characterized as a problem-solving construct (Zelazo, Carter, Reznick, & Frye, 1997). This theory proposes that executive function spans four distinct phases of problem solving and can be analyzed at the level of these phases or as a more general construct. Additional research distinguishes between "hot" and "cool" executive function during early childhood (Zelazo & Muller, 2002). According to this model, "hot" aspects of executive function are those that are more affective in nature, such as self-regulation and decision making, while "cool" aspects are more cognitive, such as working memory and the use of flexible rules.

Despite differences in perspectives on the structure of executive function, researchers do agree on the importance of the preschool years in the development of these skills along with the development of language, social competence, self-regulation, symbolic thought, and more (e.g., Carlson, 2005). In fact, such rapid increases in a wide range of cognitive abilities only increase the complexity of defining executive function and the difficulty of measuring it. There are a number of tasks assessing aspects of executive function during toddlerhood, but these tasks have shown mixed results, especially in the younger ages, due to the higher cognitive demands associated with most. Difficulty arises from achieving the delicate balance of finding tasks that not only interest (and entertain) toddlers but also uniquely tap individual aspects of executive function. As such, any task attempting to measure executive function as either a single or multiple factors inherently measures individual differences in a range of other cognitive abilities, thus suffering from a problem of "task impurity" (Miyake et al., 2000).

In contrast, executive function is a commonly studied construct in samples of children and adults diagnosed with autism spectrum disorder (ASD). In fact, an entire branch of the literature has suggested that all of the cognitive and social deficits evident in individuals with ASD are due to overarching deficits in executive function. The "executive dysfunction" theory focuses on the rigidity and invariance of many of the behaviors typically associated with ASD and explains these behaviors as an inability to execute higher order cognitive functions. For example, the tendency for individuals with ASD to become "stuck" while performing an action and the repetitive and stereotypical behaviors associated with ASD are viewed as an inability to flexibly shift attention between stimuli (Hill, 2004; Hughes, Russell, & Robbins, 1994; Pennington & Ozonoff, 1996; Pennington et al., 1997). Although this particular hypothesis has lost ground with accumulating research showing that some individuals with autism do not exhibit such deficits, it presents an intriguing set of questions for exploring the early development of executive function in individuals with autism.

A number of studies have linked autism to deficits in executive function, looking specifically at prefrontal cortex development (Bishop, 1993; Gilbert, Bird, Brindley, Frith, & Burgess, 2008; Just, Cherkassky, Keller, Kana, & Minshew, 2007; Ozonoff et al., 1991). Because prefrontal cortex maturation is not thought to occur until 12 months of age or later, it stands to reason that many manifestations of ASD (deficits in development) cannot be recognized until after this age. There exists a lack of diagnostic information for children as young as 24 months, so it is difficult to show any concrete relation between early executive function skills and autism at this age.

Although the research on executive function deficits in young children with ASD is robust, it must be noted that a few studies have failed to find evidence of executive control deficits in 3- and 4-year-olds with ASD (Dawson et al., 2002; Griffith, Pennington, Wehner, & Rogers, 1999). In addition, research in this age range of children with other neurodevelopmental disorders, such as attention deficit/hyperactivity disorder (ADHD), is relatively scarce. Several studies have looked at deficits in executive function tasks in individuals with ADHD both in comparison to typically developing individuals and those diagnosed with ASD (Goldberg et al., 2005; Happé, Booth, Charlton, & Hughes, 2006; Ozonoff & Jensen, 1999; Pennington & Ozonoff, 1996).

A meta-analysis of the research on executive function deficits in individuals diagnosed with ADHD (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) looked across 83 studies of children and adolescents to examine trends in EF. The researchers found consistent weaknesses in multiple measures of executive function, but found the most significant effects in response inhibition, vigilance, working memory, and planning. These results support long-held claims that deficits in frontal areas of the brain lead to difficulties across multiple aspects of executive function; however, these deficits are less severe than in ASD. The most robust finding across this area of research is that individuals with ADHD have more difficulties in assessments of response inhibition (Barkley, 1997; Brandimonte, Filippello, Coluccia, Altgassen, & Kliegel, 2011; Chelune et al., 1986; Pennington & Ozonoff, 1996).

Executive function impairments have been studied in a range of other neurodevelopmental disorders, such as Tourette syndrome (Hovik, et al., 2014; Ozonoff & Jensen, 1999), fragile-X syndrome (Garner, Callias & Turk, 1999; Hooper et al., 2008), and obsessive-compulsive disorder (Lewin et al., 2014; Watkins et al., 2005). While each of these disorders is associated with slightly different patterns of deficits, individuals exhibit varying degrees of difficulty across many, if not all, aspects of executive function.

In addition to the research exploring executive function development in atypical populations, a surge in recent research has examined the role of executive function in early childhood as it relates to later academic achievement. A meta-analysis of this research confirmed that compared to children who demonstrated typical executive function abilities in early childhood, those who had deficits in one or more areas showed significantly decreased abilities in school readiness (Willoughby et al., 2016). As a result of this link, many researchers have turned to identifying possible interventions that target executive function to improve school readiness and subsequent academic achievement (e.g., Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Diamond & Lee, 2011; Jacob & Parkinson, 2015).

In sum, overwhelming evidence supports the importance of understanding the development of executive function in early childhood, both in terms of its precursors and possible developmental trajectories. Aspects of attention discussed previously have been linked to executive function; however, the nature of this relation and the patterns of development involved have yet to be fully explored.

Patterns of Development in Other Domains

Many areas of research focus on understanding varying patterns of development that occur across the first few years of life. For example, a large body of literature discusses "early" vs "late" talkers. Research has established multiple patterns of early language acquisition, based on when children begin speaking. Much of this research has demonstrated that children who start talking later than their peers tend to eventually experience a vocabulary "spurt" and catch up (e.g., Weismer, Murray-Branch, & Miller, 1994). Some late talkers, however, do experience long-term language deficits (Paul & Riback, 1993; Paul & Smith, 1993; Rescorla & Schwartz, 1990). Additional research suggests that the longer the delay persists, especially into and after the third year of life, the less chance a child has of recovering from early language deficits (Paul, 1993).

Few studies have examined these types of growth patterns across other domains of cognition. Moilanen and colleagues (2009) looked at patterns of improvement in inhibitory control across early childhood. Although they found different trajectories, their research questions focused primarily on external predictors, such as parenting and socio-economic status (Moilanen et al., 2009). In another study, Kochanska and colleagues (2000) examined the early development of effortful control. They found that focused attention in infancy, in addition to gender and specific parenting characteristics, predicted greater effortful control in toddlerhood; that effortful control improved and stabilized across time; and that it had strong ties to later social development (Kochanska, Murray, & Harlan, 2000). While this study does take into account antecedents or predictors of cognitive change, it does not identify distinct patterns of development. These studies begin to fill a gap in our understanding of early trajectories of specific aspects of cognitive development, but we still lack knowledge of the cognitive abilities that lead to or stem from these different patterns.

More recent research has identified multiple early trajectories of autistic symptomatology and developmental abilities directly related to ASD. For example, Brian and colleagues (2014) identified a number of profiles to describe cognitive development across typically- and atypically-developing infants and toddlers. They established three distinct trajectories: inclining, stable-average, and declining, and found that these trajectories predicted ASD diagnostic status. They also emphasized the importance of monitoring early behaviors in order to pick up on these trajectories as early as possible (Brian et al., 2014).

Other research on children at risk for or diagnosed with ASD suggests that impairments may be present early on, or that early development appears to be typical but then plateaus or even regresses (Landa, Gross, Stuart, & Faherty, 2013; Landa, Holman, & Garrett-Mayer, 2007). Furthermore, Fountain and colleagues (2012) studied a large population of children with ASD and established six distinct trajectories in the domains of social, communication, and repetitive behaviors. These trajectories accounted for both the starting points and rates of improvement or decline across the different outcomes. While it is widely known that ASD is a heterogeneous disorder, this research confirms the wide array of possible developmental trajectories (Fountain, Winter, & Bearman, 2012). What still remains to be fully understood, however, are the underlying mechanisms that drive these different patterns and their outcomes.

The underlying theme across these areas of research is the variability of rate of development. When studying young children, it is important to consider not only individual differences in behaviors at specific times but also how, when, and how fast individual children develop certain skills. Although the previously discussed research on trajectories of development has aided our understanding in certain domains, more research is warranted on the patterns of development in other aspects of cognition, such as attention and executive function. Additionally, we do not have a solid understanding of the causes or long-term effects of these different patterns. The toddlerhood and early childhood years are hugely important due to increased plasticity and the greater potential for altering the course of impaired trajectories. Obtaining a grasp on these patterns and an understanding of the early behaviors that predict these developmental trajectories could be a vital step in creating and defining appropriate early interventions for children who show early signs of cognitive difficulties. Significant research has been conducted with the goal of identifying behaviors during infancy that may be predictive of atypical development associated with autism spectrum disorder. One example of this research is the development of the First Year Inventory (FYI; Baranek, Watson, Crais, & Reznick, 2003; Reznick, Baranek, Reavis, Watson, & Crais, 2007). The FYI is a parent report measure of infant behaviors that aims to identify infants at risk for an eventual diagnosis of autism and has been utilized in ongoing research at the University of North Carolina at Chapel Hill.

Preliminary Research

The Early Development Project (EDP) in UNC-Chapel Hill's Department of Allied Health used North Carolina birth records to recruit participants. The researchers obtained completed First Year Inventories (FYIs) from the parents of more than 9500 children over the course of the multi-year study. Infants who scored above a certain criteria on two domains of risk (social-communication and sensory-regulatory) on this parent report measure were flagged as "at risk" for an eventual diagnosis of ASD and were invited to participate in a randomized control trial of an early intervention. Infants not at risk were available for other research projects, and a subset of them constitutes the sample the present study.

With the goal of establishing a different approach to harvesting data from the FYI, three three attention-based constructs were created: responding to attention coordination (RAC), initiating attention coordination (IAC) and sensory and attentional engagement (SAE) (Stephens, Sabatos-Devito, & Reznick, under review). See the Appendix (Table 1) for the distribution of items in each construct.

> *RAC* (responding to attention coordination) involves <u>an adult's initiation of a bid</u> for attention and/or interaction with a child and the child's subsequent response (or lack of response or delayed response). The key to inclusion of an item in this construct is that the adult is initiating some act or communication in an attempt to elicit the attention and/or engagement of the child. The <u>adult</u> must clearly be <u>initiating</u> an interaction with the child or bidding for attention (for a variety of purposes) from the child through a behavioral, emotional, or communicative act. The adult's bids can include vocalizations, gestures, bodily actions, and/or offering, showing, or acting on a toy or object directed toward the child. The child's response may involve orienting (turning to or looking at), emotionally reacting, or reciprocating with an action in response to an adult-initiated bid for attention or engagement. If the wording of the item is such that the direction of the interaction is not clear (i.e., who is the initiator and who is the responder) or the child is the initiator of the interaction or bid for attention, then the item is not included.
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> *IAC* (initiating attention coordination) involves a <u>child's active bid</u> for a social partner's attention for a variety of purposes, including drawing attention to him- or herself, acquiring a desired object, toy or other item, or engaging in a desired activity. To elicit an adult's attention, the child may use communicative behaviors including gaze, gestures,

and/or vocalizations. The child must clearly be initiating an interaction with an adult or bidding for attention (for a variety of purposes) from an adult through a behavioral, emotional, or communicative act. Based on previous research, initiating joint attention and initiating behavioral requests can be considered related constructs involving slightly different levels of skill and underlying motivation. IAC collapses across these two distinctions, building on, but also broadening the scope beyond, the strict definitions associated with initiating joint attention. If the wording of the item is such that the direction of the interaction is not clear (i.e., who is the initiator and who is the responder) or the adult is the initiator of the interaction or bid for attention, the item is not included.

SAE (sensory and attentional engagement) refers to the degree to and manner in which a child attends to and/or acts on objects, sensory features of objects, or his/her own body. Behaviors can include visually examining, acting on, or exploring objects, body parts, or sensory features. Examples that may represent SAE include visual focus on objects, sensory stimuli, or body parts, focused or limited exploration, or perseverative action repertoires. Items that involve merely automatic, reflexive orienting to sensory stimuli are not included.

In addition, the scoring of the FYI was adjusted from the previous method of assigning "risk points" to a more dimensional method (scores of 1 through 4 for each item). This new scoring method created continuous distributions of the scores representing each construct, with each showing a range of variability. Low average scores for a construct represent higher (better) levels of functioning; higher scores suggest attentional deficits. A good way to think about the score is to insert a word such as "deficits" or "challenges," so a low score means few deficits or challenges. For example, a child with a low score on RAC would turn quickly to his or her name and easily follow bids for joint attention. On the other hand, a child with high RAC may need multiple prompts before a response is elicited or may not respond at all. A child with a low IAC score frequently and appropriately makes bids to others for joint attention, such as to ask for a favorite toy. High IAC would suggest a child who does not or is unable to purposefully make a bid for an adult's attention. Preliminary analyses suggest that the IAC score at 12 months may not be particularly informative, as most initiating joint attention abilities are only beginning to emerge at this age (discussed previously). However, additional data will lend further evidence to the utility of this construct. Lastly, a child with a low SAE score is more likely to explore many aspects of his or her environment and not become fixated on a particular dimension of a toy or object. A child with a high score on SAE, however, may show perseverative or repetitive behaviors or spend excess time exploring the sensory features of objects, behaviors commonly associated with ASD. For the analyses in the current study, a composite FYI attention variable was created by averaging the three attention constructs, and this variable was used to simplify analyses and interpretability.

The analyses for wave 1 of the current study (a longitudinal project conducted by our laboratory) using a subset of the large group of EDP participants (sample described below). Parents of 30-month-old toddlers were invited to complete a series of online surveys and to bring their toddlers to our laboratory for a battery of assessments. A number of analyses have already been conducted using the online survey data. We looked at predictive values of the individual 12-month attention constructs as well as attention profiles (children who fell on the high or low end of the constructs). Findings from the parent-report surveys suggested that attentional behaviors at 12 months have significant value in predicting attentional, temperamental and social behaviors at 30 months (Sabatos-Devito, 2015). These initial findings provided support for the use of the FYI attention constructs; however, the next step was to determine the value of these constructs for predicting behaviors even later in development, as well as for their relation to early developmental trajectories.

The Present Study

The goal of this study was to delve further into the development of attentional and executive control across the first few years of life, and specifically to understand more about the influence of early attentional behaviors on the different patterns of cognitive development in toddlerhood and early childhood. Cognitive development was explored through the measurement of attentional behaviors, attentional control and executive function from 12 months to 42 months. Using the three attention constructs from the First Year Inventory (FYI) as predictors, the current study analyzed both laboratory-based and parent report measures of attentional behaviors and executive function to explore and discuss patterns of development.

Specific Aims

Specific Aim 1: To determine the relation between attentional skills at 12 months and the *change* in attentional control and aspects of executive function between 30 and 42 months. To examine this specific aim, I made use of the 12-month attention constructs derived from the First Year Inventory (FYI) and the measures of attentional control and executive function at the 30- and 42-month assessments, including both laboratory measures and parent-report surveys. I hypothesized that better attentional skills at 12 months would be predictive of greater improvements in performance, based on change scores calculated from these follow-up data of both executive and attentional control at 42 months.

Specific Aim 2: To determine the role of attentional control in the relation between attentional skills at 12 months and executive function at 42 months. Data from the 30-month phase of this study (wave 1) showed significant relations between attention skills at 12 months and a variety of parent-reported constructs at 30 months, including measures of attentional control. Given the pattern of development of attentional and executive control over the first few years of life, I hypothesized that attentional control at 30 months would function as a moderator between 12-month attentional skills and 42-month executive function, such that higher attentional control would result in a stronger relationship between 12-month attention scores and 42-month executive function scores.

Specific Aim 3: To validate laboratory-based measures of executive function at 30 and 42 months with a parent-report measure of executive function at 42 months. Analyses for this specific aim included data from both the 30- and 42-month laboratory visits, as well as 42-month parent-reported executive function (EF). Laboratory assessments included measures of working memory, response inhibition and set shifting. The Behavior Rating Inventory Rating of Executive Function – Preschool version (BRIEF-P; Gioia, Espy, & Isquith, 2003) parent report measure included subscales of inhibition, shifting, and working memory (plus plan/organize and emotional control, which are considered but are not a point of emphasis), along with a global EF composite score and multiple indices combining different subscales. I hypothesized that our 30-month laboratory-based measures of EF would show a weak to moderate correlation with 42-month parent-reported EF, and that laboratory-based individual differences at 30 months would predict both laboratory-based and parent-report scores at 42 months. Further, I expected that the 42-month laboratory assessments would correlate more strongly with the parent-reported scales than would the 30-month assessments, primarily due to temporal factors.

Chapter 2. General Methods

Participants

Children within one month of 42 months (3 ½ years) of age, and their parents, were recruited from the same database of individuals that was used for the 30-month wave of data collection. While the methods of recruitment for the 42-month wave are discussed here, the process for the 30-month wave was identical aside from the window during which participation could occur (three weeks before or after turning 30 months; for more detail, see Sabatos-Devito, 2015). This database included names of parents who filled out the FYI when their children were 12 months and who agreed to be contacted for follow-up studies, but did not include infants who met the dual-domain risk criteria to be invited for the intervention study. It also only included those children who would turn 42 months old within our planned timeline for data collection. Parents and their children were recruited via phone call by trained research assistants and then emailed a link to our online surveys. Reminder emails were sent up to two times as necessary. All parents were invited to complete the online surveys, and those families who lived within 25 miles of Chapel Hill, NC, were asked to additionally participate in the laboratory portion of the study. Of the 618 parents contacted (with whom we were able to speak), most agreed to complete the online surveys ($N = 585$). See Appendix, Table 2 for the numbers of parents contacted and possible outcomes. All parents were sent a "thank you" email after the completion of the laboratory visit and/or online surveys.

We obtained at least partially-completed surveys from 82% of parents who agreed to participate (*N* = 479), with 79.3% of these containing complete survey data (*N* = 380). The survey was set up such that it was possible for parents to pause and pick up where they left off without having to start again from the beginning. As such, we were able to see what surveys had been started. If a child aged out (past 42 months of age), we were able to close “in progress” surveys and use those data that parents had provided during the appropriate window. These accounted for the 99 incomplete surveys. In each of these, parents completed at least one first full survey after the demographics section. Of the 479 parents completing these sets of surveys, 218 had also participated in the 30-month wave, allowing us to compare between groups as well as to conduct longitudinal analyses.

All children were within one month of turning 42 months (3 ½ years) of age at the time parents completed the survey. The surveys include data for approximately the same number of males and females (*n* = 246 males, 51.4%), and the majority of the sample was Caucasian (*n* = 423, 88.7%). The vast majority of respondents were the mothers of the target children. Most mothers had at least a 4-year college degree (*n* = 421, 90%). Almost half of the overall sample had completed some post-graduate education (*n* = 227, 48.5%). The sample included families of relatively high socioeconomic status, with over half of the parents reporting annual incomes of over $90,000 (*n* = 270, 57.1%). Almost half of the target children were first-born (*n* = 220, 45.9%). Thirty-one children in this sample were reported as having been given diagnoses of ASD, sensory processing/integration disorder and/or a language/communication disorder at some point prior to 42 months. See Table 1 for complete details about the survey samples at 30 and 42 months.

One-hundred thirty parents agreed to the laboratory component of the study, and we obtained at least some usable visit data for 108 children. See Appendix, Table 3 for the breakdown of participants who agreed to the laboratory visit. Three of the children were not part of the survey sample as their parents did not complete the online surveys within the one-month window despite multiple reminders. Of the 108 children with usable data, 42 had previously visited in the 30-month wave (out of a total of 76 completed 30-month visits).

Half of the 108 children who participated in the laboratory assessments were male and half were female (54 each). The laboratory sample was largely Caucasian (*n* = 88, 83.8%). Maternal education and household income for this sample was comparable to the survey sample, with a majority of mothers having at least a 4-year college degree (*n* = 99, 95.2%) and high SES (over $90,000 annual income; *N* = 73, 69.5%). Six of the children who visited the laboratory had diagnoses. See Table 1 for a complete breakdown of laboratory participant characteristics.

Although data from both the 30- and 42-month waves of data collection were included in this investigation, the majority of analyses reported here evaluated 42-month outcome data or the change between 30- and 42-months parent-reported behaviors or laboratory task performance.

Table 1. Complete participant demographics

	30-mo. Survey Sample, $N = 347$ N (%)	42-mo. Survey Sample, $N = 479$ N (%)	30-mo. Lab Sample, $N = 76$ N (%)	42-mo Lab Sample, $N = 108$ N (%)	Survey Repeat, $N = 229$ N (%)	Lab Repeat, $N = 42$ N (%)
Child Gender						
Male	170 (49.0)	246 (51.4)	39 (51.3)	54 (50.0)	118 (51.5)	21 (50.0)
Female	177 (51.0)	233 (48.6)	37 (48.7)	54 (50.0)	111 (48.5)	21 (50.0)
Race						
Caucasian	304 (88.1)	423 (88.7)	65 (87.8)	88 (83.8)	204 (89.1)	35 (83.3)
African American	21 (6.1)	25 (5.2)	2 (2.7)	6 (5.7)	12 (5.2)	1 (2.4)
Asian	10 (2.9)	16 (3.4)	5 (6.8)	6 (5.7)	6 (2.6)	3 (7.1)
Other	10 (2.9)	13 (2.7)	2 (2.7)	5 (4.8)	7 (3.1)	3 (5.1)
Mother Education						
Completed HS	7 (2.0)	6 (1.3)	1 (1.4)	0	3 (1.3)	0
Some college*	36 (10.5)	41 (8.8)	0	5 (4.8)	19 (8.4)	1 (2.4)
4-year College Grad.	140 (40.8)	194 (41.5)	32 (43.8)	36 (34.6)	95 (42.0)	17 (40.5)
Post-graduate	160 (46.7)	227 (48.5)	40 (54.8)	63 (60.6)	109 (48.2)	24 (57.1)
Household income						
Less than $35,000	18 (3.5)	21 (4.4)	2 (2.7)	5 (4.8)	14 (6.2)	0
$35,000-$60,000	62 (18.1)	72 (15.2)	9 (12.2)	10 (9.5)	34 (15.0)	3 (7.1)
$60,000-$90,000	84 (24.6)	110 (23.3)	15 (20.3)	17 (16.2)	52 (22.9)	8 (19.0)
$90,000-$150,000	110 (32.2)	163 (34.5)	20 (27.0)	42 (40.0)	84 (37.0)	17 (40.5)
Greater than $150,000	68 (19.9)	107 (22.6)	28 (37.8)	31 (29.5)	43 (18.9)	14 (33.3)
Birth Order						
First-born	168 (48.8)	220 (45.9)	35 (47.3)	52 (49.5)	116 (50.7)	19 (45.2)
Second-born	125 (36.3)	183 (38.2)	25 (33.8)	40 (38.1)	79 (34.5)	17 (40.5)
Third born or later	51 (14.8)	76 (15.9)	14 (18.9)	13 (12.4)	34 (14.9)	6 (14.3)
Diagnosis						
ASD	2	4	0	1	2	0
Sensory Processing	4	5	0	1	2	0
Communication	13	18	1	4	8	0
Other**	7	12	2	3	5	1

Notes:*Includes Vocational or Trade School degree, Associates or 2-year degree, and courses toward college degree
**Other diagnoses include gross motor delay, ADHD, verbal apraxia, social anxiety, and ADEM (Acute Disseminated Encephalomyelitis)

Measures and Procedures – Preliminary Research

The First Year Inventory (FYI; Baranek et al., 2003): The FYI is a 63-item parent-report questionnaire measuring 12-month-olds' behaviors representing two domains of behaviors relevant to ASD: social-communication and sensory-regulatory. Each of the domains was subdivided into four constructs (Reznick et al., 2007). Most items (n = 46) are rated on a 4-point scale (never, seldom, sometimes, often), and there are also 14 multiple choice items, two open-ended questions inquiring about concerns and physical/medical characteristics of the child, and one item asking about consonant sounds produced by the child. The FYI generated risk scores for the following outcomes: social-communication, sensory-regulatory, total risk, and risk percentile. For specific information regarding the creation and scoring of the FYI, along with recruitment for the samples used to design the measure, refer to Baranek et al. (2014), Reznick et al. (2007), and Watson, Baranek, Crais, Reznick, Dykstra, & Perryman (2007). Only the attention constructs derived from the FYI (Stephens et al., under review) were used in the current study.

A variety of executive function tasks were administered during the 30-month laboratory visit. All visits took place in an off-campus laboratory setting in Chapel Hill, NC. For all of the tasks, the child sat across from the experimenter and the parent sat in a chair behind the experimenter (with the exception of a few children who would not complete the tasks without a parent sitting next to them). All assessments were recorded (video and audio). Although our tasks targeted attentional, cognitive, social, and sensory abilities, only those that measured aspects of EF directly were included in the analyses for this study. These tasks specifically assessed the three primary factors of executive function: working memory, set shifting, and response inhibition.

Spin the Pots (Müller et al., 2012, adapted from Diamond, Prevor, Callender, & Druin, 1997): In this working memory task, the experimenter placed two distinctly-painted pots onto a Lazy Susan and a sticker under each. The experimenter then covered the pots with a cloth and spun the Lazy Susan. The pots were uncovered and the child was asked to find a sticker, presumably using the distinctive paint as a cue. Once the child found one sticker and placed it in his or her bag, the pot was put back on the Lazy Susan, both pots were again covered and spun, and then the child was asked to find the remaining sticker. The process was repeated with 2 pots, twice with 3 pots, and twice with 4 pots. The entire task lasted 5-10 minutes. This working memory task tested how well children could remember under which pots they had already searched. The outcome variable (score) was based on how many times children had to search before finding the stickers, so for this task, lower scores represented better working memory skills.

Shape Sorting (Stephens, Shankar & Reznick, in prep): This set shifting task is a modified version of the Dimension Change Card Sort task, which measures set shifting in young children (Frye, Zelazo, & Palfai, 1995; Zelazo, 2006). The experimenter held a bin containing blocks of different shapes (cube and sphere) and colors (yellow and green). The experimenter demonstrated the first sorting rule (according to shape or color, with the order counterbalanced across participants) and then asked the child to finish sorting the blocks. If the child sorted incorrectly, the experimenter corrected the child, but counted it as an error. After all of the blocks had been sorted, they were dumped back into the original bin. The experimenter then demonstrated sorting the blocks by the other dimension and asked the child to finish sorting the new way. If the child sorted incorrectly, the experimenter corrected the child, but counted it as an error. Throughout the task, no shape or color words were used, to account for differences in vocabulary. The task lasted approximately 5 minutes, and the outcome variable was the number of errors made by the child after changing dimensions, with higher scores thus representing poor shifting abilities.

Reverse Categorization (Müller et al., 2012, adapted from Carlson, Mandell, & Williams, 2004): This task yields a measure of response inhibition in young children. In the first phase, the experimenter demonstrated, while verbalizing, putting a red block into a corresponding red bucket and a blue block into a blue bucket. The experimenter asked the child to continue to sort the blocks one at a time until all blocks had been sorted (16 blocks total, 8 of each color). Then, the experimenter told the child that they were going to dump out the blocks and play the game a different, "silly" way, and again demonstrated and explained the new rule twice: red blocks into the blue bucket and blue blocks into the red bucket. For the remaining 16 blocks, the child selected and sorted one block at a time. This tested how well a child could inhibit the prepotent response of putting blocks in the bucket of the same color, a response that is not only more dominant but was also what she or he had been first asked to do. If the child sorted incorrectly, the experimenter corrected him or her, but counted it as an error. Similar to the Shape Sorting task, higher scores on this task were indicative of poor response inhibition.

Parent-report measures:

We collected parent-report data during the 30-month wave via online surveys using Qualtrics Survey Software. Parents completed a series of online questionnaires, including demographics questions; the Social Responsiveness Scale, Second Edition (SRS-2.0; Constantino & Gruber, 2012); the Early Childhood Behavior Questionnaire – Short Form (ECBQ; Putnam, Gartstein, & Rothbart, 2006); and the Behavioral Dimensions Questionnaire (BDQ; Goldman, unpublished).

Social Responsiveness Scale, Second Edition (SRS-2.0; Constantino & Gruber, 2012): This scale is designed to measure social deficits and can be used with children as young as 2.5 years. The SRS-2.0 yields a total raw score, with higher values indicating more severe social impairment (consistent with autistic symptomatology). This measure includes 65 items scored on a 4-point Likert scale ranging from 'Not True' to 'Almost Always True.' This scale was included in the current study as an exploratory measure given the previously-described links between ASD and deficits in attentional behaviors and executive function.

Early Childhood Behavior Questionnaire – Short Form (ECBQ; Putnam et al, 2006): This measure is designed to assess dimensions of temperament in children between 18 and 36 months of age. The short form includes 107 items and the same rating scale and dimensions as the full ECBQ. Parents are asked to rate the frequency of specific child behaviors during the past two weeks on a 7-point Likert scale ranging from 1 (never) to 7 (always). This measure identifies 18 subscales of temperament that are organized into three primary factors: effortful control, surgency/extraversion, and negative affectivity. In this study, we focused specifically on the impulsivity, inhibitory control, attentional shifting, and attentional focusing subscales of this measure.

Behavioral Dimensions Questionnaire (BDQ; Goldman, unpublished): This measure is intended to capture behaviors that reflect a child's attentional capacities across a variety of contexts and includes 30 items that are each rated on a 5-point Likert scale ranging from 0 (never/almost never/not typical at all) to 5 (always/almost always/very typical). The BDQ was developed to measure attentional behaviors such as focused attention, appropriate dual focusing (maintaining focus while being aware of the larger environment), distractibility, perseveration or inability to shift focus, inattentiveness to others' behavioral state, and unfocused or unoccupied.

For the 30-month wave, we created three factors: focused attention, attentional control, and social engagement. These factors include 23 of the 30 items in the questionnaire and show good internal consistency. See Appendix, Table 4, for information regarding the factor structure of the BDQ. Since the BDQ is not a published measure, correlations between these subscales and the attention subscales of the Early Childhood Behavior Questionnaire (ECBQ) were examined to get an estimate of validity. Moderate to high correlations suggest that the BDQ is likely measuring behaviors similar to those measured by the widely validated ECBQ (see Table 2).

Table 2. Correlations between BDQ and ECBQ attention subscales (30-month scores reported)

	BDQ Subscales	
	Attentional Control	Focused Attention
ECBQ Subscales		
Attentional Shifting	.52	.50
Attentional Focusing	.47	.55

Note: All correlations $p < .001$

Procedure – 42-month wave

A battery of tasks was administered at the 42-month laboratory visit, including some of the same executive function assessments from the 30-month visit, along with additional measures of each of the main factors of EF. (The reverse categorization task from the 30-month assessment was replaced due to a ceiling effect found at 30 months.) These tasks were used to create individual scores for each of the EF factors (working memory, response inhibition, and set shifting). Although 108 children visited our laboratory and provided at least some usable data, the sample size for each task varied due to a number of factors, including child refusal, experimenter error, etc., as can also be seen in Table 2.

Working memory tasks:

Spin the Pots (as described previously)

Musical Corsi (adapted from the McCarthy Scales of Children's Abilities, MSCA, McCarthy, 1972; Corsi, 1972): This is another measure of working memory in which children are asked to repeat sequences of block tapping. Predetermined sequences were tapped onto an 11-key xylophone. Each number of taps was repeated twice, starting with one tap and increasing by 1 until the child could not correctly replicate the sequence on either trial of a given length. The outcome variable was an overall score that takes into account trials during which the child hits the correct notes but in the wrong order. A child's score thus reflects a proportion of sequences copied correctly, so higher values (closer to 1) here represent better performance.

After conducting this assessment with approximately 45 participants, we opted to change the protocol. Children were exhibiting difficulty with sequences greater than two notes, so there was very little variability. It is possible that difficulties may have arisen as a result of the keys being laid out sequentially on the xylophone, thus imposing an order. Further, many children struggled with using the mallet to strike the keys and achieve the same tone as the administrator. We switched to an array of bells to keep the musical aspect of the task but to remove the imposed sequence of the xylophone and the difficulties with the mallet. Specifically, children who used the xylophone reached an average sequence length of 3.5 notes sequences, while those who used the bells reached an average of 4.7 notes, $t(83) = -11.01$, $p < .01$. Participants' scores on the tasks, which take into account the number of sequences presented, were also significantly different. Children who participated in the xylophone version scored, on average, .46 out of 1, while those who participated in the bell version averaged .54 out of 1, $t(83) = -2.08$, $p < .05$). So. for the purposes of this study, only data from the bell version were included.

Set shifting tasks:

Shape Sorting (as described previously)

Dimension Change Card Sort (Frye et al., 1995; Zelazo, 2006): During this task, children sorted cards that varied on two different dimensions: shape and color. In the first phase, children were asked to sort the cards based on one dimension; in the second phase, they had to shift and sort according to the second dimension. The outcome measure was the number of cards sorted incorrectly after the switch, so higher scores on this task represented poor shifting abilities.

Response inhibition tasks:

Dragon & Lion (adapted from Reed, Pien, & Rothbart, 1984): This task is similar to the familiar game of "Simon Says" and the children were asked to perform the actions instructed by one puppet and inhibit those actions that were instructed by the other. Stimuli in our task were a dragon puppet (which children were to follow) and a lion puppet (which they were to ignore). In this game, children were required to suppress the prepotent response of acting out all instructions from the puppets. Research suggests that there is vast improvement in this task between ages 3 and 4 (Carlson, 2005), so we expected that using this measurement at 3 ½ would yield a range of individual differences.

After running this task with approximately 15 participants, however, we found that children were having difficulty understanding the rules, especially the notion of doing "nothing" when told by the lion to perform an action. As a result, we modified the protocol to include a teaching portion. The researcher administering the task was a different person than the primary assessor, as we did not want to confound performance by using the same person with whom the children had been listening and following instructions during the earlier part of the session. During the instructions and practice rounds, the primary assessor remained in the room with the child and the puppet administrator. The primary assessor listened to the instructions and performed the practice rounds with the child, who was advised to watch the primary assessor for assistance in knowing what was meant by "not doing what the lion said." The primary assessor then left the room for the actual trials. This introduced an observational learning component to the task, but since this was only to clarify instructions and make sure children understood the rules of the game, we did not believe it affected performance in a way that compromised the task. Further, there were a number of children who appeared to understand the rules during teaching and practice but were unable to inhibit the response of listening to both puppets, resulting in a dramatic increase in the variability in performance with this adjustment. The outcome variable for this task was how many trials the child performed incorrectly (out of a possible 12), so lower scores represented better inhibition.

Day-Night (Gerstadt, Hong, & Diamond, 1994): In this task, children were presented with cards that were either white with a yellow sun or black with a white moon and stars. This task was Stroop-like, in that children were instructed to say "day" when they saw the moon card and "night" when they saw the sun card. The task began with a practice trial with each card and the practice trials were repeated if necessary. If a mistake was made in one of the first two trials, the experimenter reminded the child of the rules and the first two counted as practice trials. The outcome variable was the number of cards the child named incorrectly out of 14 or 16 (if additional practice trials were needed). Proportions were used to account for the differences in practice trials needed. Similar to the Dragon & Lion task, lower scores on this task represented better inhibitory skills.

Table 3. Laboratory task completion

	Usable data	Assessor Error	Refusal	Child did not understand	Parent interference	Audio-visual complications	Task not administered*
Shape Sorting	95	8	2	1	0	0	0
Spin the Pots	105	1	1	0	0	1	0
Day-Night	86	10	2	4	3	3	1
Dragon & Lion	79	2	6	0	0	2	16
DCCS	86	14	4	0	1	3	0
Musical Corsi**	53	1	7	1	0	2	44

Notes: *These values represent the tasks run before we established the final protocol (Dragon & Lion) and the Musical Corsi tasks with the xylophone, since only the bell-trials were included in these analyses. The 1 Day-Night not administered was for a child diagnosed with ASD who was nonverbal and thus not capable of responding to the task requirements.

** These values only include participants who participated in the task after switching to bells (all xylophone trials listed as "not administered")

Parent-report measures:

During the 42-month wave of data collection, online surveys were administered to parents. The battery included a series of demographic questions (same as before), the previously described SRS-2.0 (Constantino & Gruber, 2012) and BDQ (Goldman, unpublished), as well as the Behavior Rating Inventory of Executive Function – Preschool Version (BRIEF-P; Gioia et al., 2003), and the Children's Behavior Questionnaire – Short Form (CBQ; Putnam & Rothbart, 2006). See Table 4 for the total numbers for each survey across the 30- and 42-month waves of data collection.

Social Responsiveness Scale – 2nd edition (SRS-2.0, as described previously)

Behavioral Dimensions Questionnaire (BDQ, as described previously)

Behavior Rating Inventory of Executive Function – Preschool Version (BRIEF-P; Gioia et al., 2003): This measure is a 63-item inventory that assesses aspects of executive function in preschool-aged children, or between ages two and five years. Parents rate their children on a 3-point Likert scale (never, sometimes, often), with higher scores on each scale representing more deficits in executive function. The BRIEF-P reports a global executive composite (GEC) score, which sums responses for all items in the measure. Additionally, the BRIEF-P includes subscales for inhibit, shift, emotional control, working memory, and plan/organize, as well as an emergent metacognition index (EMI: plan/organize + working memory), an inhibitory self-control index (ISCI: inhibit + emotional control), and a flexibility index (FI: shift + emotional control). The composite score (GEC) and indices were used in primary analyses for this study; individual subscales were only considered for exploratory purposes where indicated.

Children's Behavior Questionnaire – Short Form (CBQ; Putnam & Rothbart, 2006): This measure is designed to assess aspects of temperament in children aged 3 to 7 years. It includes 94 items loading onto 15 scales, with each item scored on a 7-point Likert scale ranging from 1 (extremely untrue of your child) to 7 (extremely true of your child). Generally, items are scored such that higher scores represent stronger abilities on each of these scales, but scores were reversed to be consistent with the other measures (higher scores represent poor parent-reported behaviors). In the current study, we focused specifically on the attentional focusing, inhibitory control, and impulsivity scales (the CBQ does not include an attentional shifting subscale similar to that in the ECBQ).

Table 4. Number of participants with full data for each survey

	30-month wave	42-month wave
BRIEF-P	N/A	478
SRS 2.0	345	447
BDQ	313	427
ECBQ/CBQ*	320	404

Notes * The ECBQ is designed for reporting on children aged 18-36 months, and the CBQ for children 3-7 years. Although these are different measures, they are designed to measure the same factors, so direct comparison between the two should not be problematic.

Data Analysis

Laboratory data were scored by trained research assistants. Prior to scoring, all videos were viewed by the primary researchers to determine (1) whether or not tasks were administered correctly; (2) if there was any interference from parents, child refusal, or lack of understanding; or (3) if there were any other complicating factors that would make some of the data unusable (see Table 2 for these numbers). All tasks were double-scored to ensure reliability. Initial reliability (before resolving discrepancies) was very high, ranging from 79% to 100% agreement, so very few tasks needed to be viewed a third time. The tasks with the lowest initial reliability were Day-Night (79.1%) and Spin the Pots (81.9%). Discrepancies in Day-Night scoring were primarily due to difficulties hearing or understanding what the child said for each card. For Spin the Pots, most discrepancies occurred when the child picked up more than one pot at a time. All discrepancies were resolved by a third coder. All online survey data were compiled and merged with the 30-month data to allow for longitudinal analyses of children for whom we have data at two time points. All data were analyzed using SAS 9.3 (SAS Institute, Cary, NC). Analyses addressing the main study questions were decided upon *a priori,* whereas others were carried out in a more general fashion to understand the data. Thus, the findings for each are presented below as either “primary” or “exploratory.”

All data (laboratory and survey) were analyzed to determine if there were differences in laboratory performance or parent-reported behaviors as a function of whether or not parents and children previously participated in the first wave (30 months). Independent samples *t*-tests were conducted to determine the existence of significant differences between those children and parents who participated at one time point or both in order to eliminate concerns about practice or repeated assessment effects. Laboratory results showed no practice effects at 42 months of previous participation at 30 months. In the parent report surveys, a few of the 42-month outcome variables (BDQ attentional control and social engagement and CBQ impulsivity) were significantly different between repeat and first-time responders, such that parents who were completing the survey for the second time tended to rate their children lower (better performance) than those who were completing it for the first time (and had not participated at 30 months). As the analyses for this study rely primarily on data from both time points, it is possible that these effects could impact the interpretation of some of the findings. These issues will be considered within the context of each specific aim as necessary. There were no significant differences in performance in any of the laboratory tasks between the children who were visiting for the second versus the first time.

Data were also analyzed to determine differences between children who had attended at least some structured preschool and those who primarily stayed at home with a parent or nanny or attended a home-based daycare. Information about childcare was not probed in the parent report online series of surveys, but it was derived from one of the questions included in a brief survey completed by parents who brought their children to the laboratory. Of the 108 children whose parents completed this survey, 81 had been attending a structured preschool at least part-time. Independent samples *t*-tests were conducted to determine whether or not attendance in a structured preschool setting was associated with performance on laboratory tasks or parent-reported outcomes. There were no differences between groups on any of the parent-reported outcomes, but one of the laboratory tasks (Musical Corsi) showed a significant difference in performance between these two groups, $t(51) = 2.65$, $p < .05$. Interestingly, and contrary to expectations, children who had attended structured preschool performed significantly worse than those whose primary childcare was provided by a parent, nanny, or in home-based daycare.

Although this result has some interesting implications and could be discussed in great detail, given that it was only found in one assessment and that this particular assessment had a much smaller sample size than the other tasks, it will not be discussed further.

Chapter 3. Specific Aim 1

To determine the relation between attentional skills at 12 months and the *change* in attentional control and aspects of executive function between 30 and 42 months.

Specific Methods

Analyses for SA1 utilized the joint attention and sensory engagement constructs (RAC – responding to attention coordination, IAC – initiating attention coordination, and SAE – sensory and attentional engagement) from the FYI to represent attention skills at 12 months. To look at improvement in attentional control and executive function between 30 and 42 months, change scores for the variables described below were calculated by subtracting the 30-month score from the 42-month score. Only those participants for whom we had obtained data during both the 30- and 42-month waves were included. In these analyses, attentional control is represented by the attentional control, social engagement, and focused attention subscales of the Behavioral Dimensions Questionnaire (BDQ, $N = 195$) as well as the attention focusing and impulsivity subscales from the Early Childhood Behavior Questionnaire and Childhood Behavior Questionnaire (ECBQ and CBQ, $N = 189$). To explore the relationship between attentional behaviors and autistic symptomatology, change scores for the Social Responsiveness Scale – 2nd edition (SRS-2.0, $N = 219$) were also calculated.

For all variables, lower scores represent better abilities. All of the First Year Inventory (FYI) attention constructs as well as the FYI attention composite score, the Behavioral Dimensions Questionnaire (BDQ) subscales, the SRS-2.0 and the Early Childhood Behavior

Questionnaire/Childhood Behavior Questionnaire (ECBQ/CBQ) impulsivity subscale are typically scored as such (lower scores are better). The attention focusing subscale of the ECBQ/CBQ was reverse-scored to be consistent with other measures.

Results

To examine the effect of 12-month FYI attention scores on the change between 30- and 42-month scores, initial exploratory analyses compared the predictive value of 12-month attentional behaviors on 30- and 42-month scores. The purpose of these analyses was to establish whether (1) the 12-month FYI attention constructs were still predictive of 42-month scores and (2) the nature of the difference in predictive value between 30 and 42 months. As expected, most of the models were stronger for the 30-month outcomes than those at 42 months, but most remained significant at 42 months (see Table 1.1). The top section of this table presents multiple linear regression models looking at the predictive value of the three attention constructs on outcomes at 30 and 42 months. The next columns of results describe the predictive value of the FYI attention composite score (the average of the three attention constructs) using simple linear regression models. The bottom table presents another set of simple linear regression analyses, this time exploring the predictive value of each of the attention constructs individually. These values provide information about which of the constructs may be driving the significance of the full model or the value of the composite score.

Interestingly, a few models were stronger for 42-month scores, suggesting that the effect of 12-month parent-reported attention may have more complex relations with the outcome variables than initially thought. These results confirmed the predictive value of the FYI attention constructs for 30-month parent-reported behaviors and demonstrated that they still have predictive value one year later. Given these relations, the next step was to explore how outcome behaviors changed between 30 and 42 months.

Table 1.1. Comparison of models predicting 30- and 42-month outcomes from 12-month FYI attention scores

	Full model (RAC+IAC+SAE)		FYI Attention mean	
	T1	T2	T1	T2
	F, R^2	*F*, R^2	*B (SE)*	*B (SE)*
BDQ				
Attentional Control	12.83**, .168	9.69**, .132	0.78** (0.16)	0.72** (0.14)
Focused Attention	8.20**, .114	7.49**, .105	0.74** (0.15)	0.57** (0.14)
Social Engagement	6.94**, .098	**8.78**, .121**	0.60** (0.16)	0.59** (0.14)
ECBQ/CBQ				
Attentional Focusing	3.81*, .058	2.74*, .042	0.65** (0.22)	0.66* (0.28)
Impulsivity	1.67, .026	**5.01**, .075**	-0.04 (.35)	**0.87** (0.23)**
SRS-2.0				
SRS sum	7.45**, .094	**9.78**, .120**	8.93** (2.61)	**22.66** (4.31)**

	RAC		IAC		SAE	
	T1	T2	T1	T2	T1	T2
	B (SE)	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*
BDQ						
Attentional Control	0.55** (0.17)	0.49** (0.15)	0.19+ (0.11)	**0.29** (0.09)**	0.61** (0.11)	0.45** (0.10)
Focused Attention	0.48** (0.16)	0.27+ (0.14)	0.34** (0.10)	0.24** (0.09)	0.42** (0.11)	0.39** (0.09)
Social Engagement	0.40* (0.17)	0.38* (0.15)	0.16 (0.10)	0.16+ (0.09)	0.47** (0.11)	0.47** (0.10)
ECBQ/CBQ						
Attentional Focusing	0.44* (0.22)	0.29 (0.28)	0.21 (0.14)	**0.44* (0.18)**	0.46** (0.15)	0.29 (0.19)
Impulsivity	-0.47 (0.35)	**0.76** (0.23)**	0.13 (0.22)	**0.43** (0.15)**	-0.002 (0.23)	**0.38* (0.16)**
SRS-2.0						
SRS sum	8.23** (2.60)	**15.87** (4.42)**	0.19 (1.82)	**7.70* (3.07)**	5.57** (1.44)	**10.90** (2.43)**

Notes: +*p* < .10, **p* < .05, ** *p* < .01; RAC = responding to attention coordination; IAC = initiating attention coordination; SAE = sensory and attentional engagement; FYI attn. mean. = composite FYI attention score (average of three constructs; T1 = 30-month wave; T2 = 42-month wave; BDQ = Behavioral Dimensions Questionnaire; ECBQ = Early Childhood Behavior Questionnaire; CBQ = Childhood Behavior Questionnaire; SRS-2.0 = Social Responsiveness Scale – 2nd edition; **values in bold represent improved fit for 42-month score over 30-month score**

To analyze the effect of 12-month attentional behaviors on change scores, regression analyses were conducted, all controlling for the 30-month score. In other words, with these models we explored the extent to which the 12-month attention scores could predict adjusted 42-month scores. In these regression analyses with performance at 30 months being controlled, there were few significant relations between FYI attention scores and parent report change scores (see Table 1.2). The first column reports the results of linear regression models predicting change in the subscale score from the FYI attention composite score (the average of the three individual FYI attention constructs). When results were significant or trending, the relation between 12-month attentional behaviors and change in these outcomes between 30 and 42 months was such that higher (worse) 12-month scores predicted higher (worse) adjusted 42-month scores. Given that improvement would be indicated by lower scores at 42 months than at 30 months, these results supported the initial hypotheses (see Table 1.2).

Table 1.2. Regression models predicting change scores from FYI attention scores (all values controlling for 30-month scores).

	12-month Parent-reported Attention			
	FYI attn. *B (SE)*	RAC mean *B (SE)*	IAC mean *B (SE)*	SAE mean *B (SE)*
BDQ Subscales				
Attentional Control	0.39 (.15)*	0.18 (.15)	0.21 (.10)*	0.16 (.09)+
Focused Attention	0.24 (.15)+	0.03 (.14)	0.04 (.10)	0.19 (.08)*
Social Engagement	0.36 (.15)*	0.19 (.14)	0.06 (.05)	0.25 (.05)**
ECBQ/CBQ Subscales				
Attention Focusing	0.32 (.21)	0.15 (.20)	0.31 (.13)*	-0.01 (.14)
Impulsivity	0.54 (.23)*	0.57 (.23)*	0.30 (.15)*	0.12 (.16)
SRS-2.0				
SRS sum	11.55 (2.67)**	6.96 (2.82)*	5.55 (1.66)**	5.78 (1.80)**

Notes: +*p* < .10, **p* < .05, ***p* < .01; FYI attn. = composite FYI attention score (average of three constructs); RAC = responding to attention coordination; IAC = initiating attention coordination; SAE = sensory and attentional engagement; BDQ = Behavioral Dimensions Questionnaire; ECBQ = Early Childhood Behavior Questionnaire; CBQ = Childhood Behavior Questionnaire; SRS-2.0 = Social Responsiveness Scale – 2^{nd} edition

Upon further examination of the data, it was discovered that controlling for performance at 30 months obscured a considerable amount of variability in changes in performance between the 30- and 42-month assessments. Additionally, the interpretability of the change score results was relatively difficult. The variability in change can be seen in Table 1.3 in which descriptive statistics concerning the calculated change scores are displayed. Although the mean change scores were mostly negative, as expected, the scores ranged from improvement to worsening on the order of multiple points in each direction.

Table 1.3. Change score statistics

	Mean (sd)	Median	Least Improved	Most Improved
BDQ Subscales				
Attentional control	-0.14 (.51)	-0.14	1.43	-1.57
Focused attention	-0.31 (.49)	-0.33	1.22	-1.59
Social engagement	-0.16 (.50)	-0.14	1.29	-1.57
ECBQ/CBQ Subscales				
Attention focusing	.02 (.89)	0.00	2.67	-2.50
Impulsivity	-.99 (1.4)	-1.08	3.58	-4.33
SRS-2.0				
SRS sum	-28.9 (9.6)	-31.0	15	-48

Notes: BDQ = Behavioral Dimensions Questionnaire; ECBQ = Early Childhood Behavior Questionnaire; CBQ = Childhood Behavior Questionnaire; SRS-2.0 = Social Responsiveness Scale – 2nd edition

To obtain a clearer understanding of the nature of the changes over time in these constructs, individual patterns of change for the BDQ attentional control subscale were plotted (see Figure 1.1). Although this figure only shows the variability in patterns of change in the attentional control subscale, similar patterns were observed in the other outcomes of interest. This figure illustrates the high degree of variability in 30-month scores, 42-month scores, and the slopes of the changes, suggesting that it would be useful to carry out more in-depth analyses of the data.

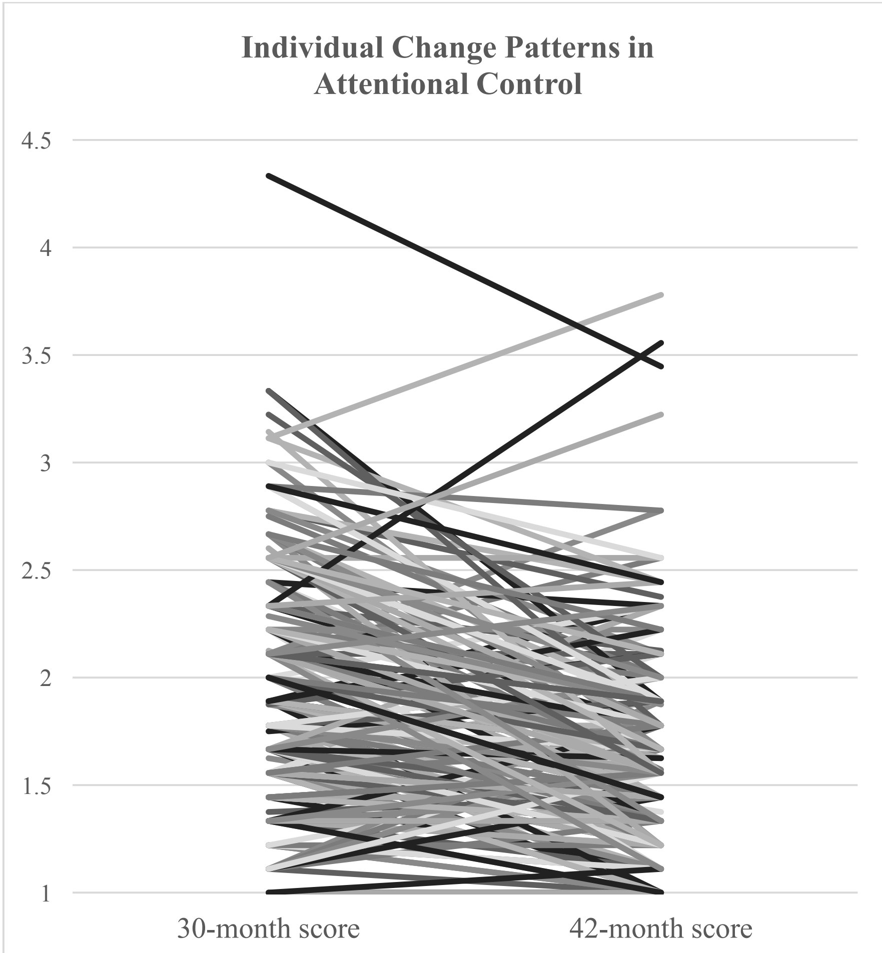

Figure 1.1. Change in attentional control between 30 and 42 months (individual trajectories plotted)

Inspection of Figure 1.1 indicates clearly that some parents reported no change in their child's behaviors, but no change could reflect good behaviors (low scores) or difficulty (high scores) at both time points. Additionally, whereas many children were reported as having improved scores (a decrease from 30 to 42 months), another group had worse scores at the second time point (an increase in score between 30 and 42 months). Consideration of these individual patterns of change guided the creation of distinct groups based on both the starting point (30-month score) and the direction and rate of change.

Four subgroups were created: (1) low score at 30 months and low score at 42 months (good-good); (2) low score at 30 months and high score at 42 months (good-poor); (3) high score at 30 months and low score at 42 months (poor-good); and (4) high score at 30 months and high score at 42 months (poor-poor). These groups were created by first using a median split of 30-month scores into high and low groups. Then, each of those groups was split at the median again, resulting in four subgroups of children based on their parents' ratings of attentional control at both the 30- and 42-month assessments.

This process was repeated for each variable of interest: attentional control, focused attention, and social engagement from the Behavioral Dimensions Questionnaire (BDQ), attentional focusing and impulsivity from the Early Childhood Behavior Questionnaire/Childhood Behavior Questionnaire (ECBQ/CBQ), and the raw score from the Social Responsiveness Scale – 2nd edition (SRS-2.0). Although using median splits is not always the preferred way of establishing subgroups, it is appropriate in an exploratory analysis in which the goal is to examine general patterns of individual change. Further, dividing the sample this way also creates relatively similar group sizes (see Table 1.4), and, as such, a median split was deemed appropriate.

Table 1.4. Group sizes for change comparison analyses

	Group 1 (Good-good)	Group 2 (Good-Poor)	Group 3 (Poor-Good)	Group 4 (Poor-Poor)
BDQ				
Attentional control	50	51	43	51
Focused attention	55	56	45	39
Social engagement	56	59	43	37
ECBQ/CBQ				
Attentional focusing	36	43	60	42
Impulsivity	39	53	41	48
SRS-2.0				
SRS Sum	49	55	55	60

Notes: BDQ = Behavioral Dimensions Questionnaire; ECBQ = Early Childhood Behavior Questionnaire; CBQ = Childhood Behavior Questionnaire; SRS-2.0 = Social Responsiveness Scale – 2nd edition

Figures 1.2 and 1.3 represent the mean 30- and 42-month scores for the Behavioral Dimensions Questionnaire (BDQ) attentional control groups and the Early Childhood Behavior Questionnaire/Childhood Behavior Questionnaire (ECBQ/CBQ) impulsivity groups, respectively, and illustrate the four distinct trajectories explored. Similar patterns were also observed in the other groups (BDQ – focused attention and social engagement; ECBQ/CBQ – attentional focusing). In both of these figures, the four distinct trajectories are clear. Both groups 1 (good-good) and 4 (poor-poor) do not show a great deal of change over time, but the difference in scores at both time points is clear. Groups 2 (good-poor) and 3 (poor-good) represent children whose parents reported more substantial changes in behaviors, either as improvement (Group 3) or as worsening (Group 2).

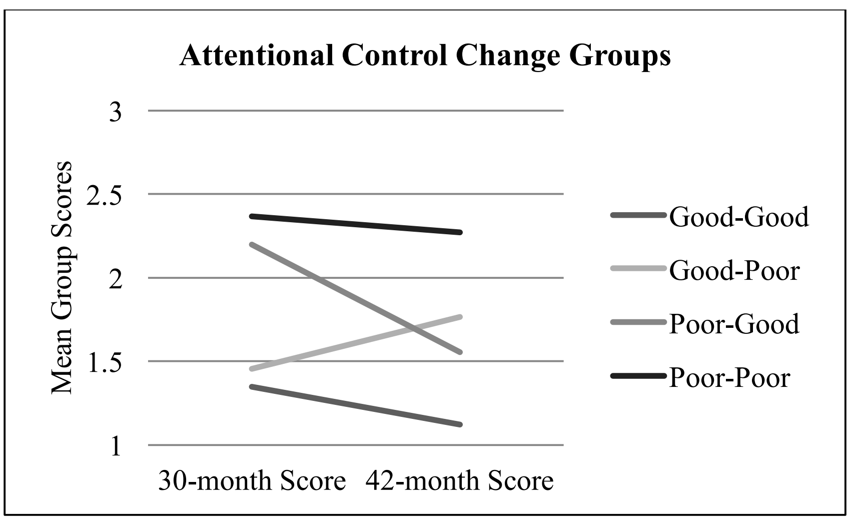

Figure 1.2. Four patterns of change in attentional control (mean scores plotted)

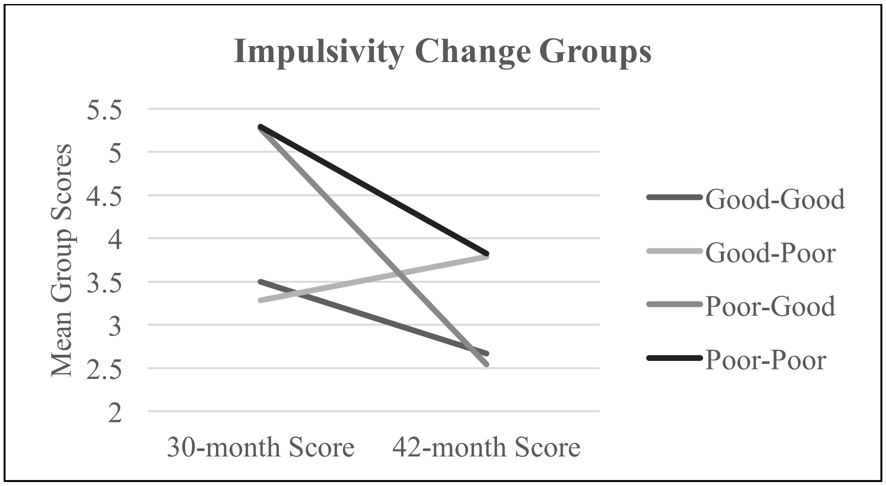

Figure 1.3. Four patterns of change in impulsivity (mean scores plotted)

It should be noted that one outlier was removed from the Social Responsiveness Scale – 2nd edition (SRS-2.0) dataset in the first set of analyses (regressions with change scores). SRS scores for one child worsened by 36 points (increased) between 30 and 42 months. Given that this value was more than six standard deviations above the mean of change scores, SRS data for this child were excluded from initial change analyses. However, because the subgroup analysis strategy was designed to specifically examine individual trajectories, this outlier was included in the analyses presented here. (Note: upon further examination of this outlier, it was discovered that the child had been diagnosed with ASD between 30- and 42-month survey completions, which could affect how the parent rated behaviors specific to this measure, one that is specifically designed to assess ASD severity.)

To examine the characteristics of the children who exhibited different patterns of change from 30 to 42 months of age, a series of general linear model analyses was conducted to determine the extent to which the four subgroups differed in terms of their 12-month FYI attention scores. These analyses represented *a priori* tests of the main hypotheses and involved direct comparisons of the FYI attention means across each group for each of the outcome variables, and the results are presented in Table 1.5. *F* values reported refer to the degree of differences found in each model. Significant comparisons for each variable are also reported, with these comparison analyses controlling for Type 1 experiment-wise error rate.

The first column of Table 1.5 represents the differences in the FYI attention composite scores across the four change subgroups for each outcome of interest. Both F and R^2 values are reported to indicate the extent to which the 12-month attention scores differ as a function of change group. Although the model was significant, the composite score was significantly different only between BDQ attentional control groups 1 (good-good) and 4 (poor-poor). Across other variable subgroups, additional significant comparisons emerged. For example, the BDQ focused attention subgroups had significantly different FYI attention composite scores between groups 1 (good-good) and 3 (poor-good), groups 1 (good-good) and 4 (poor-poor), and groups 2 (poor-good) and 4 (poor-poor).

Similar patterns emerged across the individual FYI attention scores: responding to attention coordination (RAC), initiating attention coordination (IAC), and sensory and attentional engagement (SAE). For the majority of variable subgroups, only the SAE score significantly differed among groups, with varying patterns of differences in regards to significant comparisons. The last column reports results of multiple linear regression models examining the extent to which subgroups differed as a function of all three FYI attention constructs.

Table 1.5 Differences in FYI attention scores across four change groups

	FYI Attention Mean *F*, R^2	RAC Mean *F*, R^2	IAC Mean *F*, R^2	SAE Mean *F*, R^2	Full model (RAC+IAC+SAE) *F*, R^2
BDQ					
Attentional control	8.16**, .114	3.25*, .049	3.07*, .046	10.41**, .141	9.68**, .132
Sig. comparisons	1-4	1-4	1-2	1-4, 2-4, 3-4	
Focused attention	7.31**, .103	1.89, .029	1.66, .025	7.47**, .105	8.58**, .119
Sig. comparisons	1-3, 1-4, 2-4			1-3, 1-4	
Social engagement	4.99**, .073	2.51, .038	0.24, .004	7.17**, .101	5.44**, .079
Sig. comparisons	1-2, 1-4			1-2, 1-3, 1-4	
ECBQ/CBQ					
Attentional focusing	3.75*, .057	2.05, .032	3.40*, .052	2.61, .041	3.59*, .055
Sig. comparisons	1-4, 2-4		1-4, 3-4		
Impulsivity	7.87**, .113	5.36**, .080	3.89*, .059	4.82**, .072	2.96*, .046
Sig. comparisons	1-2, 1-4, 2-3, 3-4	1-2, 2-3	3-4	1-4, 3-4	
SRS-2.0					
SRS Sum	11.11**, .134	7.00**, .089	3.76*, .050	8.75**, .109	12.74**, .151
Sig. comparisons	1-2, 1-3, 1-4, 2-4	1-4, 2-4	1-2	1-4, 2-4, 3-4	

Notes: * $p < .05$, ** $p < .01$; FYI attention mean = composite FYI attention score (average of three constructs); RAC = responding to attention coordination; IAC = initiating attention coordination; SAE = sensory and attentional engagement; BDQ = Behavioral Dimensions Questionnaire; ECBQ = Early Childhood Behavior Questionnaire; CBQ = Childhood Behavior Questionnaire; SRS-2.0 = Social Responsiveness Scale – 2nd edition

The results summarized in Table 1.5 suggest that the attention constructs derived from the FYI provide information about the change in parent-reported behaviors between 30 and 42 months. As reported in Table 1.1, the FYI attention composite predicted individual scores at both time points, but change pattern analyses showed that the nature of these predictions varied based on the trajectory of change between 30 and 42 months. Because the FYI attention composite score represents an average of the three FYI attention constructs, this score was examined more closely. Figures 1.4-1.9 illustrate the different FYI attention composite scores across each of the variable groups.

Figure 1.4 below shows the mean FYI attention composite score across the Behavioral Dimensions Questionnaire (BDQ) attentional control subgroups. As indicated in Table 1.5 and in the figure, the full model looking at group differences was significant. However, group comparisons (controlling for Type 1 experiment-wise error rate) revealed that the significance in the model was largely due to differences in groups 1 (good-good) and 4 (poor-poor)

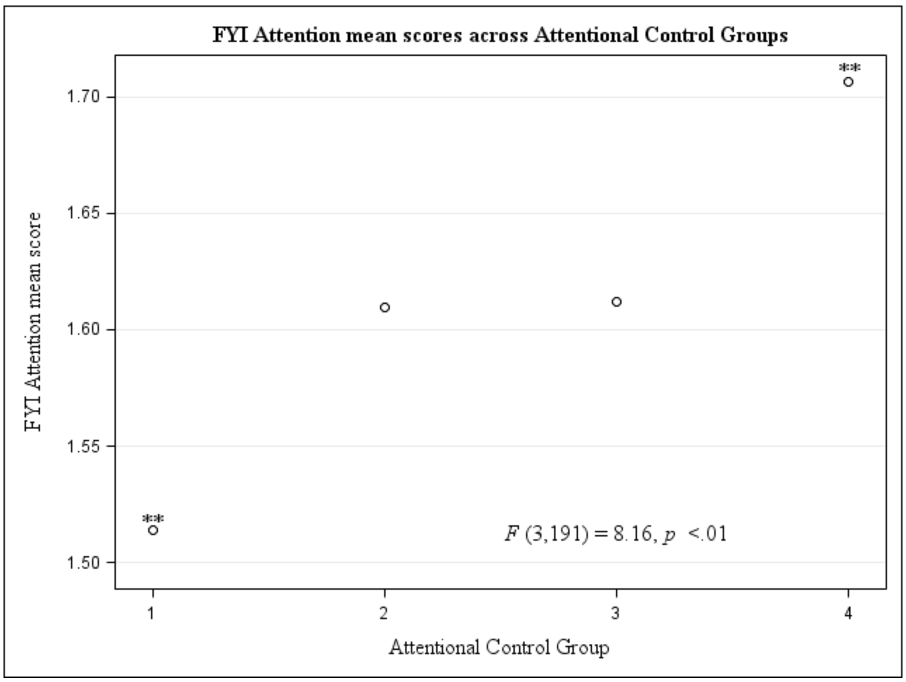

Figure 1.4. Attentional control group means of FYI attention mean score
Note: ** significant comparison, $p < .05$

Figure 1.5 illustrates the FYI attention composite means across the BDQ focused attention subgroups. Again, the full model was significant and group comparisons revealed significant differences between groups 1 (good-good) and 4 (poor-poor). Additionally, there were significant differences in the FYI attention composite between groups 1 (good-good) and 3 (poor-good) and between groups 2 (good-poor) and 4 (poor-poor).

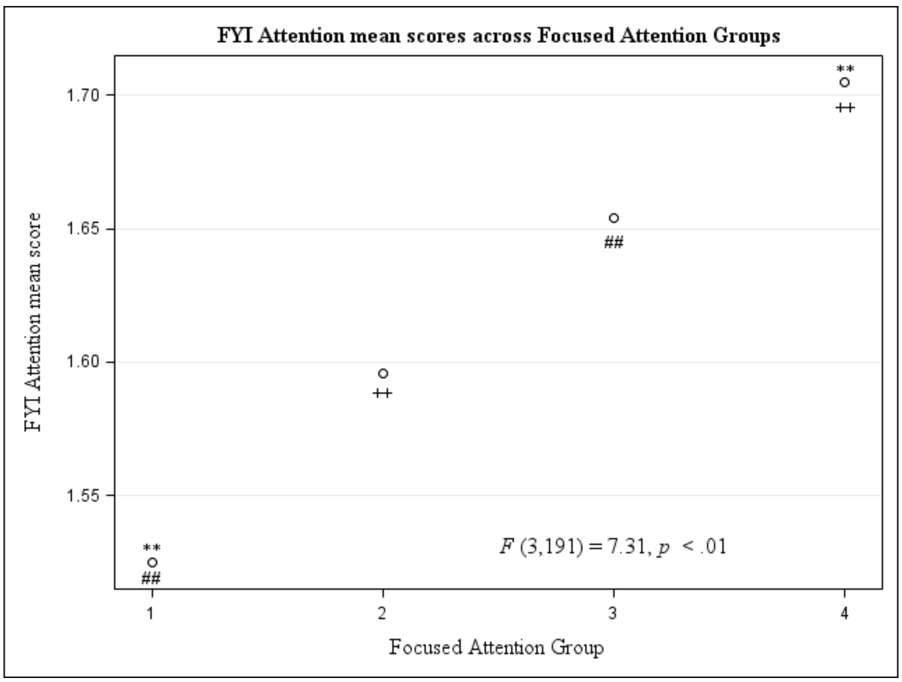

Figure 1.5. Focused Attention group means of FYI attention mean score
Note: **, ##, ++ significant comparisons, $p < .05$

Figure 1.6 illustrates the FYI composite means across the BDQ social engagement subgroups. Similar to the other BDQ subgroups, there was a significant difference in the FYI composite mean between groups 1 (good-good) and 4 (poor-poor). For these subgroups, there was also a significant difference in the FYI attention composite between groups 1 (good-good) and 2 (good-poor).

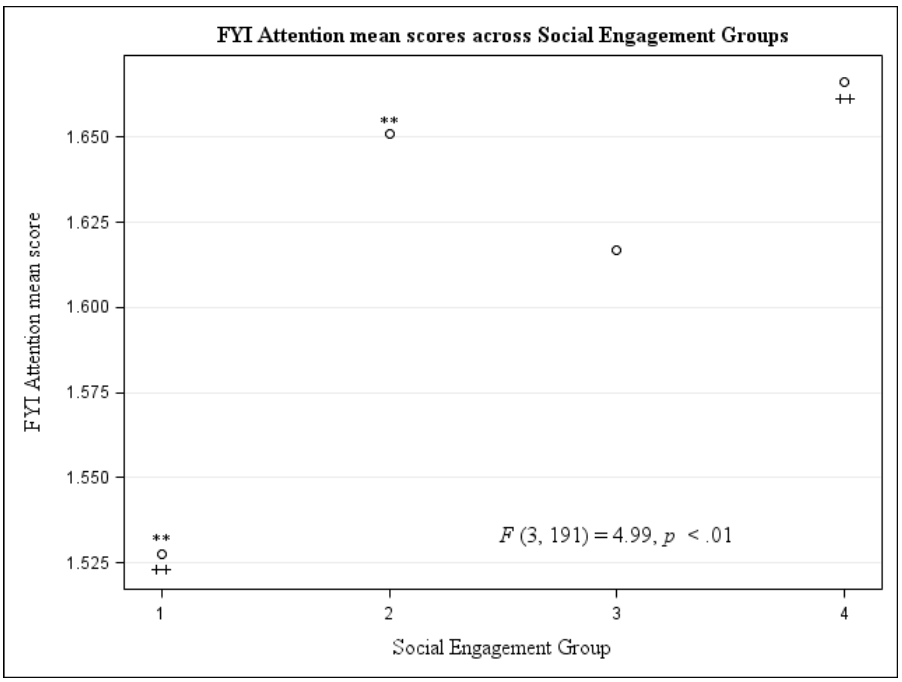

Figure 1.6. Social Engagement group means of FYI attention mean score
Note: **, ++ significant comparisons, $p < .05$

Figure 1.7 illustrates the FYI composite means across the Early Childhood Behavior Questionnaire/Childhood Behavior Questionnaire (ECBQ/CBQ) attentional focusing subgroups. Similar to the previously described BDQ subgroups, there was a significant difference in the FYI composite mean between groups 1 (good-good) and 4 (poor-poor). Additionally, there was a significant difference in the FYI attention composite between groups 2 (good-poor) and 4 (poor-poor).

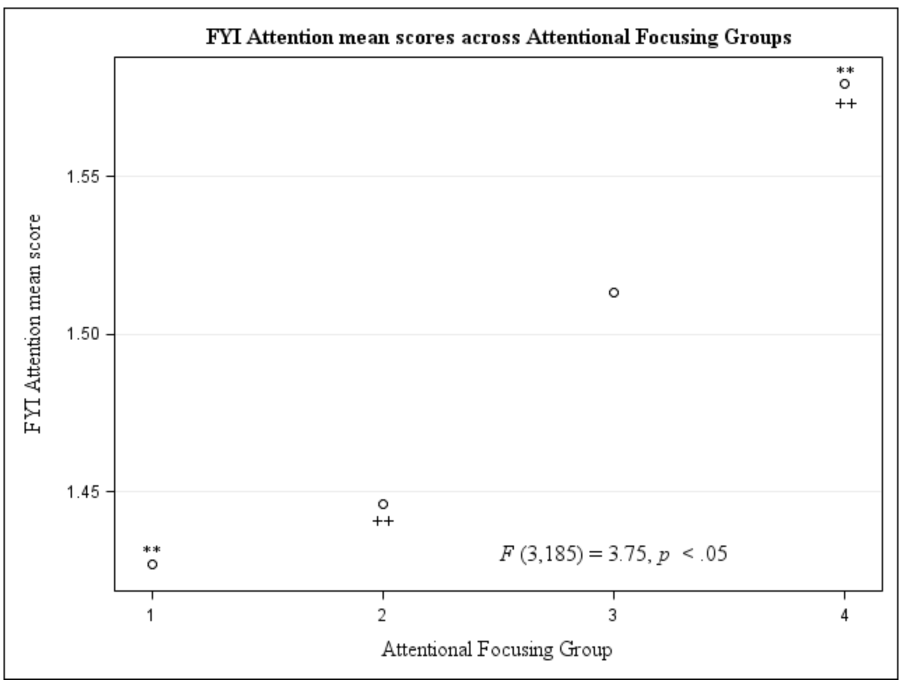

Figure 1.7. Attentional Focusing group means of FYI attention mean score
Note: **, ++ significant comparisons, $p < .05$

Figure 1.8 illustrates the FYI attention composite means across the ECBQ/CBQ impulsivity subgroups. There were many significant comparisons among these groups. Similar to the other variables described, there was a significant difference in the FYI attention composite mean between groups 1 (good-good) and 4 (poor-poor). There was also a significant difference in the FYI attention composite between groups 1 (good-good) and 2 (good-poor), between groups 2 (good-poor) and 3 (poor-good), and between groups 3 (poor-good) and 4 (poor-poor)

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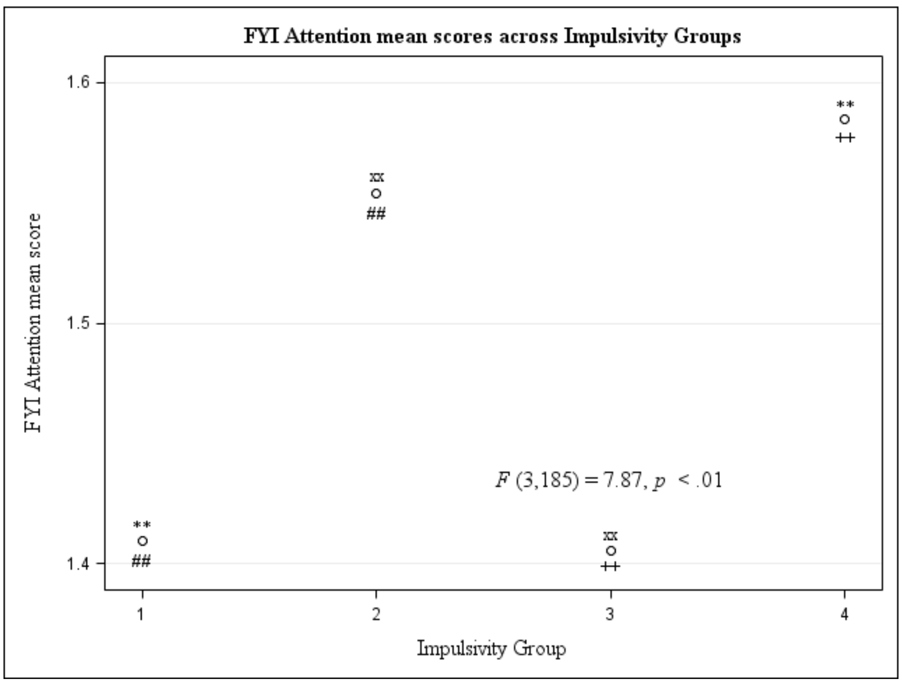

Figure 1.8. Impulsivity group means of FYI attention mean score
Note: **, ++, ##, xx significant comparisons, $p < .05$

Figure 1.9 illustrates the results of exploratory analyses comparing FYI attention composite means across the Social Responsiveness Scale – 2nd edition (SRS-2.0) subgroups. There were many significant comparisons among these groups. There were significant differences in the FYI attention composite means between groups 1 (good-good) and groups 2 (good-poor), 3 (poor-good), and 4 (poor-poor). Additionally, there was a significant difference in the FYI attention composite between groups 2 (good-poor) and 4 (poor-poor).

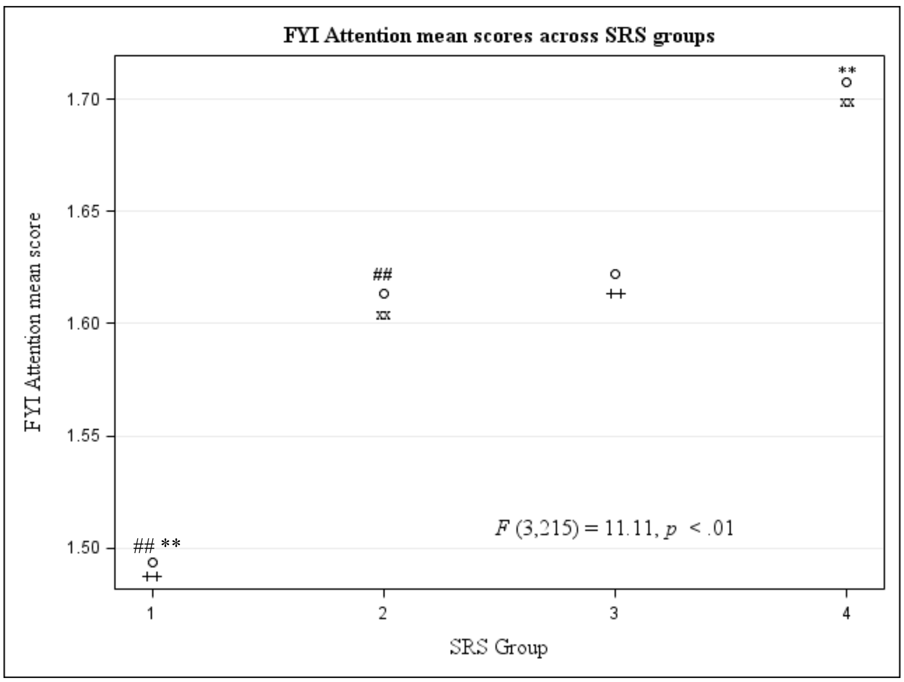

Figure 1.9. SRS group means of FYI attention mean score
Note: **, ++, ##, xx significant comparisons, $p < .05$

Specific Aim 1 Discussion

The goal of this specific aim was to explore the relation between attentional behaviors at 12 months and the change in attentional control and executive function between 30 and 42 months. Few of the initial models predicting change from 12-month attentional behaviors (controlling for 30-month score) reached statistical significance, and those that did proved somewhat difficult to interpret. As a next step, the sample was split into subgroups using a double median split, to understand contrasting patterns of change from 30 to 42 months that were obscured in the initial analyses that held 30-month performance constant.

Groups 1 (good-good) and 4 (poor-poor) both showed little to no change between 30 and 42 months, but had different 30-month scores. Although the initial analyses with performance at 30 months controlled resulted in a lack of clear findings, by accounting for different change trajectories, the data could be explored at a deeper level. When significant, most of the models resulted in significant comparisons between groups 1 and 4, results that intuitively made sense given those group patterns. Perhaps more interesting were the significant comparisons among the other groups. For example, the FYI composite score significantly differed between groups 1 and 2 defined by patterns of social engagement, impulsivity, and SRS data. These groups had similar 30-month scores; the differences were in change patterns. Specifically, individuals in group 1 maintained low (better) scores at 42 months, whereas those in group 2 were reported to have worse behaviors at 42 months. Also, there were significant differences between groups 2 and 4, when these groups were formed on the basis of the focused attention, attentional focusing, and SRS data. Contrary to the group 1 vs 2 comparison, these groups had different 30-month scores (group 2 = lower/better, group 4 = higher/worse) but had more similar scores at 42 months. Children in group 2 were reported as performing worse at 42 months, whereas those in group 4 were reported as having consistent yet poor behaviors at both time points. Approaching the data from an individual differences perspective allowed for a more detailed look into the nature of development.

A primary limitation of these analyses was the use of the double-median split to create groups. Without a clear theoretical guide for determining cut-points, however, this was the most appropriate means for establishing groups. Additionally, it must be emphasized that these analyses used only parent-reported behaviors, so even significant findings should be interpreted with caution. Parent-report questionnaires are widely used in toddler and early childhood research. However, concerns about interpretability are especially true when looking at point-to-point predictions (e.g. 12-month scores to 30- or 42-month scores), given that parents are probably more likely to remain consistent in the reporting of their child's behaviors.

Having established these different patterns of change that are influenced by 12-month attentional behaviors, the next step was to examine how these varying trajectories account for development of other cognitive skills, such as aspects of executive function. This question led to the analyses conducted in Specific Aim 2.

Chapter 4. Specific Aim 2

To determine the role of attentional control in the relation between attentional skills at 12 months and executive function at 42 months.

Specific Methods

The original hypothesis and subsequent analytic plan for this specific aim were that attentional control at 30 months would moderate the relation between 12-month attentional behaviors and 42-month executive function. However, results from Specific Aim 1 illustrate the value of examining different patterns of change between 30 and 42 months and suggest that these different patterns may be more predictive of later development than would 30-month data alone. Therefore, the moderating variables in the following analyses were derived on the basis of four contrasting attentional control patterns as discussed above in SA1 (1 - good-good, 2 - good-poor, 3 - poor-good, and 4 - poor-poor).

Analyses for SA2 used 12-month predictors based on data from the FYI attention constructs (responding to attention coordination - RAC, initiating attention coordination - IAC, sensory and attentional engagement - SAE, and the mean FYI attention composite score). Moreover, the moderator group variables were established from the attentional control, focused attention and social engagement subscales from the Behavioral Dimensions Questionnaire administered at 30 and 42 months and the attentional focusing and impulsivity subscales of the Early Childhood Behavior Questionnaire (ECBQ – 30 months) and the Childhood Behavior Questionnaire (CBQ – 42 months). The primary outcome variable was the Global Executive

Composite (GEC) score from the 42-month parent report Behavior Rating Inventory of Executive Function – Preschool Version (BRIEF-P). BRIEF-P indices (emergent metacognition index – EMI, inhibitory self-control index – ISCI, flexibility index – FI) were also included in the exploratory analyses. As these analyses required data for all three time-points, they only included participants for whom we had complete data for these measures in both waves of the study (N = 195 for BDQ analyses; N = 189 for ECBQ analyses).

Results

The relation between attentional behaviors at 12 months and parent-reported executive function at 42 months was examined using exploratory simple linear regression analyses. Table 2.1 includes the results of these analyses. The FYI attention composite variable and individual FYI attention constructs were entered as predictors (in separate models). The primary outcome variable was the global executive composite score (GEC) from the Behavior Rating Inventory of Executive Function (BRIEF-P), but regressions predicting the three main indices of the BRIEF-P (emergent metacognition index, inhibitory self-control index, and flexibility index) were also conducted (see Table 2.1).

As can be seen in Table 2.1, which reports the results of linear regression analyses predicting BRIEF-P outcomes from the 12-month FYI attention constructs, regression analyses revealed some relatively strong relations between ratings of attentional behaviors at 12 months and executive function at 42 months. To illustrate these patterns, the relation between the 12-month FYI attention composite score and the global executive composite from the BRIEF-P is displayed in Figure 2.1 This figure illustrates both the strength of the relation between these constructs and the variability among relations.

Table 2.1 Simple linear regression analyses predicting BRIEF-P scores from FYI attention constructs

	FYI attn. mean *B (SE)*	RAC mean *B (SE)*	IAC mean *B (SE)*	SAE mean *B (SE)*
BRIEF-P variables				
Global Executive Composite	16.52 (4.29)**	10.27 (4.45)*	4.67 (2.80)+	13.10 (2.91)**
Emergent Metacognition Index	7.02 (2.02)**	4.52 (2.08)*	1.86 (1.31)	5.65 (1.37)**
Inhibitory Self-Control Index	7.33 (2.01)**	3.83 (2.09)+	2.14 (1.30)	6.06 (1.35)**
Flexibility Index	4.74 (1.69)**	3.86 (1.73)*	1.22 (1.09)	3.48 (1.16)**

Notes: +*p* < .10, **p* < .05, ***p* < .01; BRIEF-P = Behavior Rating Inventory of Executive Function – Preschool Version; FYI attn. mean = composite FYI attention score (average of three constructs); RAC = responding to attention coordination; IAC = initiating attention coordination; SAE = sensory and attentional engagement;

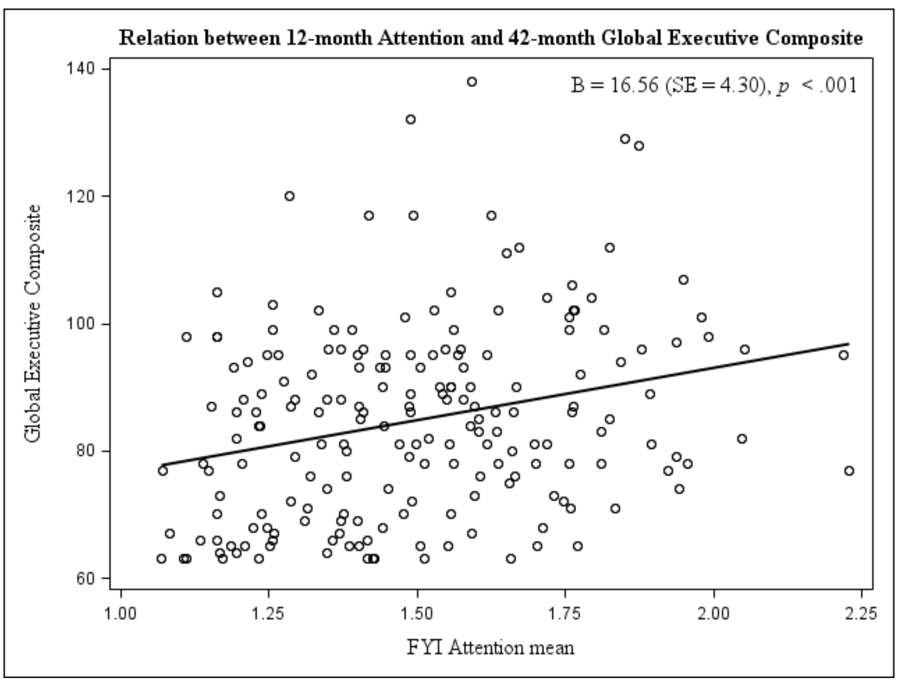

Figure 2.1. Relation between 12-month FYI Attention composite and 42-month Global Executive Composite
Note: Data come from sample with full BDQ (30 and 42 months) and BRIEF-P data (N = 195).

To explore the variability seen in Figure 2.1, an additional series of regression analyses was conducted to determine the potential moderating effect of attentional control trajectory on executive function by making use of the subgroups created in Specific Aim 1. Although subgroups were formed on the basis of the Behavioral Dimensions Questionnaire (BDQ) for each of the attentional control, focused attention, and social engagement subscales, only the attentional control groups were analyzed here. This decision was made based on results of SA1, which indicated that attentional control subgroups more consistently differed across 12-month attentional behaviors than did the subgroups formed from the other subscales of the BDQ. Further, selecting only one subscale reduced the number of analyses and risk for Type 1 error. For similar reasons, only the impulsivity groups from the Early Childhood Behavior Questionnaire/Childhood Behavior Questionnaire (ECBQ/CBQ) were used in the following analyses.

Multiple regression analyses were conducted to explore the moderating effect of attentional control subgroup on the relation between 12-month attentional behaviors and 42-month executive function as measured by the Behavior Rating Inventory of Executive Function – Preschool version (BRIEF-P). These analyses are the primary focus of this aim and were decided upon *a priori.* The models created for these analyses included BRIEF-P outcome variables, with predictors of 12-month attention construct and attentional control subgroup, and an interaction term including both predictors. This interaction term reflected the extent to which the relation between 12-month attentional behaviors and 42-month executive function varied as a function of subgroup. Table 2.2 reports the *F*-values for these interaction terms.

Table 2.2. Moderation model results for BRIEF-P indices as outcomes. *F*-values for interaction terms reported

	FYI attn. mean	RAC mean	IAC mean	SAE mean
	Outcome: Global Executive Composite			
Attentional Control	1.23	1.44	1.89+	1.22
Impulsivity	1.06	1.71	2.81*	0.07
	Outcome: Emergent Metacognition Index			
Attentional Control	1.22	1.35	1.84+	1.92+
Impulsivity	1.20	1.78	3.13*	0.12
	Outcome: Inhibitory Self-Control Index			
Attentional Control	0.90	1.92+	1.46	1.14
Impulsivity	1.36	2.08+	2.48++	0.24
	Outcome: Flexibility Index			
Attentional Control	2.37++	1.02	2.21++	1.98+
Impulsivity	0.16	0.21	0.62	0.73

Notes: $+p < .15$, $++p < .10$, $*p < .05$; BRIEF-P = Behavior Rating Inventory of Executive Function – Preschool Version; FYI attention mean = composite FYI attention score (average of three constructs); RAC = responding to attention coordination; IAC = initiating attention coordination; SAE = sensory and attentional engagement

Although there were few significant moderating effects of attentional control group on the relation between 12-month attentional behaviors and 42-month executive function, many of the models approached statistical significance. In contrast, impulsivity group significantly moderated the relation between IAC mean and the global executive composite, $F(7,180) = 2.81$, $p < .05$, and the relation between IAC mean and the emergent metacognition index, $F(7,180) = 3.13$, $p < .05$.

Given the different trajectories of development established in SA1 and the degree of variability in the relation between 12-month attention and 42-month executive function, regression analyses were conducted for each of the individual subgroups. This allowed for the comparison of the predictive value of 12-month attention across children who displayed different patterns of attentional control or impulsivity. Table 2.3 reports the sample sizes for the individual subgroup analyses.

Table 2.3. Group sizes for individual group regression analyses.

	Group 1 (Good-good)	Group 2 (Good-Poor)	Group 3 (Poor-Good)	Group 4 (Poor-Poor)
BDQ				
Attentional control	50	51	43	51
ECBQ/CBQ				
Impulsivity	39	53	41	48

Notes: BDQ = Behavioral Dimensions Questionnaire; ECBQ = Early Childhood Behavior Questionnaire; CBQ = Childhood Behavior Questionnaire

BDQ Attentional Control: In the Specific Aim 1 analyses, four subgroups were established on the basis of distinct patterns of change in attentional control between 30 and 42 months. As reported previously, there was a significant relation between the 12-month FYI attention composite and each of the BRIEF-P composites/indices (see Table 2.1 and the first column of Table 2.4 below). However, when breaking the sample into change subgroups, significance did not hold for all of the groups.

As seen in Table 2.4, for the global executive composite (GEC) outcome, the predictive value of 12-month FYI attentional behaviors was only significant for group 1 (good-good attentional control). This pattern repeated for both the emergent metacognition index (EMI) and the flexibility index (FI), but not for the inhibitory self-control index (ISCI). In addition, there was also a significant relation between 12-month attentional behaviors and 42-month flexibility index for group 3 (poor-good). These results suggest that although on the surface, 12-month parent-reported attentional behaviors strongly predict 42-month parent-reported executive function, this predictive value holds only for specific subgroups of children (see Table 2.4).

Table 2.4. Regression models for BDQ attentional control groups (FYI attention composite predictor)

	Full sample B (SE)	Group 1 B (SE)	Group 2 B (SE)	Group 3 B (SE)	Group 4 B (SE)
GEC	16.56 (4.30)**	20.03 (8.64)*	10.56 (7.42)	9.37 (6.76)	-3.90 (10.01)
EMI	7.04 (2.02)**	8.17 (3.42)*	5.34 (2.30)+	-0.64 (3.42)	-1.18 (5.05)
ISCI	7.34 (2.01)**	6.78 (4.47)	5.71 (3.63)	5.29 (3.42)	-1.52 (4.56)
FI	4.75 (1.70)**	8.93 (3.81)*	0.15 (3.03)	8.47 (3.42)*	-1.85 (3.81)

Notes: +p < .10, *p < .05, **p < .01; BDQ = Behavioral Dimensions Questionnaire; GEC = global executive composite; EMI = emergent metacognition index; ISCI = inhibitory self-control index; FI = flexibility index

Figure 2.2 is derived from the moderating model presented in Table 2.2 and illustrates the ways in which the relation between 12-month attentional behaviors and 42-month executive function varies as a function of attentional control subgroup. As a reminder, this model predicted 42-month global executive composite (GEC) from the 12-month FYI attention composite and the attentional control subgroups established in Aim 1, with an interaction term that included both predictors. Although the interaction term in this model did not reach statistical significance (suggesting little to no moderating effect), the resulting plot provides an exploratory visualization of the moderating value of attentional control group. The plot illustrates the regression lines for each attentional control subgroup. Figure 2.2 displays group 1 (good-good) showing a relatively strong relation between the 12-month FYI attention composite score and the 42-month global executive composite (GEC) score, whereas the other subgroups do not show similarly strong relations. The lines presented in this plot support the patterns described in Table 2.4, which suggest that the relation between the 12-month FYI composite and the 42-month GEC remains significant only for group 1 and not for the other subgroups.

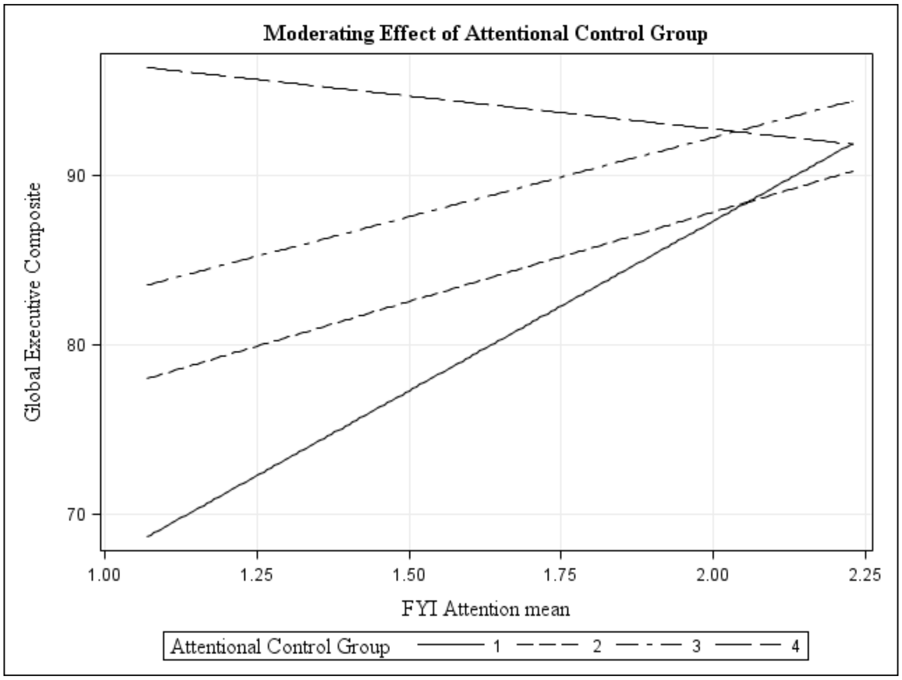

Figure 2.2. Relation between 12-month FYI attention composite and 42-month Global Executive Composite across different BDQ attentional control groups

ECBQ/CBQ Impulsivity: Consistent with the findings associated with the BDQ attentional control groups, when breaking the sample into change groups defined in terms of the impulsivity scale of the ECBQ/CBQ, significant predictive relations did not hold for all of the subgroups. As can be seen in Table 2.5, for the global executive composite (GEC) outcome, the predictive value of the 12-month FYI attention composite score was only significant for group 1 (good-good impulsivity) and group 3 (poor-good impulsivity). This pattern was repeated for both the emergent metacognition index (EMI) and the inhibitory self-control index (ISCI), but not for the flexibility index (FI) (see Table 2.5).

Table 2.5. Regression models for ECBQ/CBQ Impulsivity groups

	Full sample	Group 1	Group 2	Group 3	Group 4
GEC	15.41 (4.36)**	18.84 (6.91)**	6.12 (8.42)	19.07 (8.96)*	1.31 (9.58)
EMI	6.34 (2.06)**	8.77 (2.85)**	1.65 (4.01)	8.84 (4.35)*	0.02 (4.67)
ISCI	6.81 (2.03)**	10.10 (3.39)**	0.83 (3.94)	9.30 (4.42)*	1.15 (4.44)
FI	5.01 (1.73)	2.27 (2.81)	4.55 (3.94)	3.16 (3.42)	1.48 (3.34)

Notes: +$p < .10$, *$p < .05$, **$p < .01$; ECBQ = Early Childhood Behavior Questionnaire; CBQ = Childhood Behavior Questionnaire; GEC = global executive composite; EMI = emergent metacognition index; ISCI = inhibitory self-control index; FI = flexibility index

These different patterns of prediction from 12-month attentional behaviors to 42-month executive function are illustrated in Figure 2.3 for the four subgroups defined on the basis of impulsivity scores. This figure is derived again from the moderating model presented in Table 2.2, which predicted the 42-month global executive composite (GEC) from the 12-month FYI attention composite and the attentional control subgroups established in Aim 1, with an interaction term that included both predictors. Although the interaction term was not statistically significant, suggesting the lack of a moderating effect, the resulting plot provides an exploratory visualization of the moderating value of impulsivity group. Similar to the plot of relations for the groups derived from the BDQ attentional control, group 1(good-good) shows a strong relation between 12-month attentional behaviors and 42-month executive function. Different from the patterns of relations among attentional control groups, impulsivity group 3 (poor-good) also shows a strong relation between 12- and 42-month constructs.

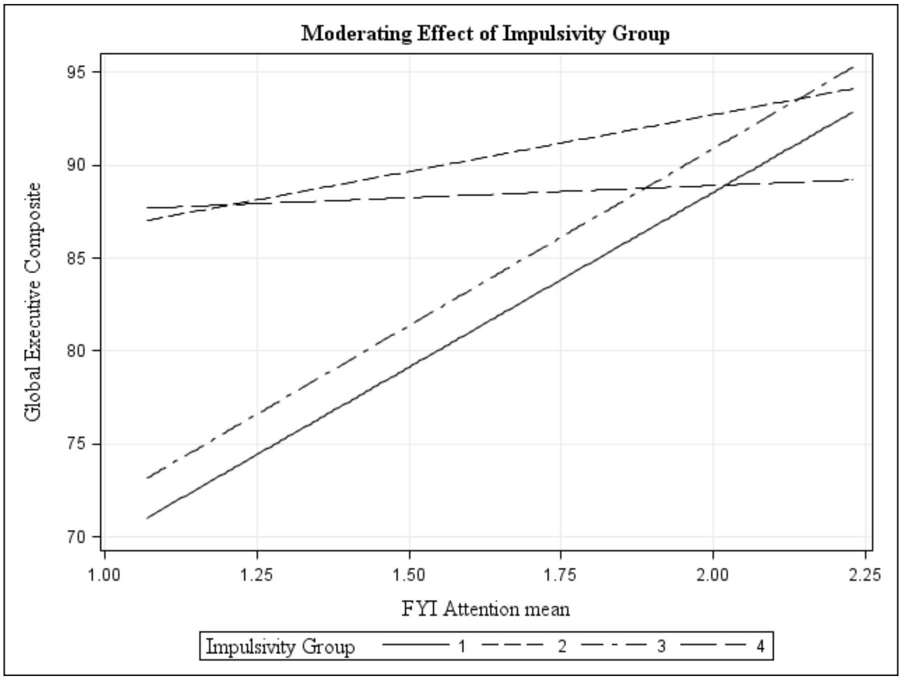

Figure 2.3. Relation between 12-month FYI Attention composite and 42-month Global Executive Composite across different ECBQ/BDQ Impulsivity groups

Specific Aim 2 Discussion

The goal of this aim was to examine the nature of the predictive value of 12-month attentional behaviors on 42-month executive function. Simple regression analyses show that for the sample of children for whom we have data at both 30 and 42 months, this predictive value is strong (reported in Table 2.1 and displayed in Figure 2.1). However, there remains a relatively high degree of variability in this relation. Results from Specific Aim 1 suggest that different patterns of change exist, and these patterns may account for some of this variability. Therefore, multiple regression models containing interaction terms were analyzed to determine the extent to which the relation between 12-month attentional behaviors and 42-month executive function varied by across the groups derived by patterns of change between 30 and 42 months. In other words, these analyses allowed the examination of whether children who exhibited different trajectories would display similar relations between 12- and 42-month constructs.

Few of the models reported in Table 2.2 reached statistical significance, however when the predictive value of 12-month attentional behaviors was examined across subgroups independently, different patterns emerged. When looking across groups derived from change in BDQ attentional control, the relation between 12-month attentional behaviors and 42-month executive function only remained significant for group 1 (good attentional control at both time points). Across groups derived from change in ECBQ/CBQ impulsivity, the relation between 12-month attentional behaviors and 42-month executive function remained significant for groups 1 (good-good) and 3 (poor-good).

For the impulsivity subgroups, groups 1 and 3 maintained significance when regression analyses were conducted for individual subgroups. Group 1 represented children who reportedly maintained good (low) levels of impulsivity behaviors between 30 and 42 months, and group 3 represented children who reportedly improved in impulsivity behaviors between these time points. In both groups, impulsivity was reported as good (low) at 42 months. Similar to the attentional control variable, stability or improvement in impulsivity may represent some underlying executive control mechanism that has already matured to some degree but lacks the efficiency to result in good executive function behaviors as defined by the global executive composite (GEC) score of the BRIEF-P.

Although moderation models did not reach statistical significance, breaking down the sample into subgroups likely resulted in a loss of power. Examining these models in a larger sample may yield significant findings. As in Specific Aim 1, primary limitations of these analyses were the reliance on parent-report data and the use of double median splits to create the subgroups. Although parent-report questionnaires may be one of the more cost- and time-effective way of obtaining data about young children, other modes of data collection, for example, laboratory assessments, are also valuable, and should also be used when appropriate and compared with the parent-report data when relevant. The goal of Specific Aim 3 was to compare children's performance on laboratory tasks of executive function with the results from the parent-reported executive function behaviors.

Chapter 5. Specific Aim 3

To validate laboratory-based measures of executive function at 30 and 42 months with a parent-report measure of executive function at 42 months.

Specific Methods

One of the main limitations of Specific Aims 1 and 2 was the use of parent report data. The goal of Specific Aim 3 was to compare parent-reported executive function behaviors with children's performance on executive function laboratory tasks. In addition to the parent-reported data from the Behavior Rating Inventory of Executive Function – Preschool version (BRIEF-P), the analyses for Specific Aim 3 included data derived from laboratory tasks administered to children at 30 months and/or 42 months of age. At 30 months, the executive function tasks included assessments of working memory (Spin the Pots, $N = 74$), response inhibition (Reverse Categorization, $N = 70$), and set shifting (Shape Sorting, N=64). At the 42-month visit, the children completed some of the same tasks as in the 30-month visit, along with additional ones. The 42-month battery included assessments of working memory (Spin the Pots, N=105 and Musical Corsi, $N = 43$), response inhibition (Day-Night, $N = 86$ and Dragon & Lion, $N = 79$), and set shifting (Shape Sorting, $N = 95$ and DCCS, $N = 86$). Data from the BRIEF-P completed during 42-month participation (online surveys) were included from parents whose children visited the laboratory during either the 30- or 42-month wave.

Results

To explore the relations among the laboratory assessments and parent-report measures of executive function, correlations among the EF variables were calculated and are displayed in Tables 3.1 through 3.3. First, inspection of these tables indicates that very few significant correlations were found, although those between performance on the 42-month Shape Sorting task and a number of the EF scales did approach trended toward significance. Second, tasks from the 42-month assessment were analyzed for correlations between those which were thought to measure the same construct. Spin the Pots and Musical Corsi (working memory) were uncorrelated, as were the Dimension Change Card Sort (DCCS) and Shape Sorting (set shifting). Only the performance on the response inhibition tasks, Day-Night and Dragon & Lion, approached significance with a correlation of .22 (p=.07). Therefore, the tasks were kept separate in subsequent analyses, instead of being combined as composites for each construct.

42-month laboratory EF and 42-month parent-report EF

Correlations between the 42-month laboratory tasks and the parent-reported BRIEF-P scores can be found in Table 3.1. Although there was generally little to no association among scores, there was a significant relation between the global executive composite (GEC) score and performance on the Shape Sorting task, $r(88) = .23$, $p < .05$. In addition, performance on the Dimension Change Card Sort (DCCS) was significantly related to that assessed by the inhibit subscale of the BRIEF-P, $r(80) = .23$, $p < .05$. Other than these two relations, the only laboratory assessment that was systematically related to the parent-reported scores was the Shape Sorting task, which was moderately related to the three BRIEF-P indices (flexibility index, inhibitory self-control index, and emergent metacognition index) and most of the subscales (shift, working memory, plan/organize, and emotional control) (see Table 3.1).

Table 3.1 Correlations between 42-month laboratory tasks and 42-month BRIEF-P scores

	Working Memory tasks		*Response Inhibition tasks*		*Set Shifting tasks*	
	Spin the Pots	Musical Corsi	Day-Night	Dragon & Lion	Shape Sorting	DCCS
BRIEF-P Indices and Subscales						
GEC	.01	.06	.03	.06	.22*	.14
FI	.08	.01	.05	.07	.21+	.05
ISCI	-.01	.11	.05	.09	.19+	.17
EMI	-.02	.03	.09	.02	.20+	.09
Shift	.10	-.03	.06	.03	.19+	.05
Inhibit	-.05	.12	.02	.08	.16	.23*
Working Memory	-.03	.01	.11	.05	.19+	.14
Plan/Organize	.01	.05	.04	-.03	.18+	.02
Emotional Control	.05	.06	-.15	.10	.18+	.04

Notes: $+p < .10$, $*p < .05$; BRIEF-P = Behavior Report Inventory of Executive Function – Preschool version; GEC = Global Executive Composite; EMI = Emergent Metacognition Index; ISCI = Inhibitory Self-Control Index; FI = Flexibility Index; DCCS = Dimension Change Card Sort

30-month laboratory EF and 42-month parent-report EF

Additional correlation analyses were run to determine the relation between performance on the 30-month laboratory assessments and parent ratings on the BRIEF-P at 42 months. Although there were no significant correlations among these variables, inspection of Table 3.2 indicates that the 30-month working memory task (Spin the Pots) was moderately related to many of the outcome variables. Working memory performance at 30 months was moderately related to parent-reported global executive composite (GEC) score, the inhibitory self-control index (ISCI), and inhibit and working memory subscales. Interesting to note is that whereas 30-month working memory performance was related to 42-month parent-reported working memory, the relation did not exist for the 42-month working memory assessments.

Table 3.2 Correlations between 30-month laboratory tasks and 42-month BRIEF-P scores

	Spin the Pots	Reverse Categorization	Shape Sorting
BRIEF-P Indices and Subscales			
GEC	.27+	-.04	.07
FI	.16	.02	.16
ISCI	.29+	-.16	.08
EMI	.26	-.02	.01
Shift	.06	.16	.12
Inhibit	.28+	-.13	-.01
Working Memory	.28+	-.04	.002
Plan/Organize	.20	.01	.02
Emotional Control	.23	-.15	.19

Notes: $+p < .10$, $*p < .05$; GEC = Global Executive Composite; EMI = Emergent Metacognition Index; ISCI = Inhibitory Self-Control Index; FI = Flexibility Index; DCCS = Dimension Change Card Sort

30-month and 42-month laboratory EF

To determine the relations among the children's performance on the laboratory measures correlations were carried out across the two assessment waves. As can be seen in Table 3.3, only one of these correlations was statistically significant: the relation between performance on the 30-month Reverse Categorization task and performance on the 42-month Day-Night task, $r(31) = .43$, $p < .05$. Both of these tasks were designed to assess the response inhibition construct of executive function.

Table 3.3 Correlations between 30- and 42-month laboratory tasks

	30-month tasks		
	Spin the Pots	Reverse Categorization	Shape Sorting
42-month tasks			
Spin the Pots	-.05	.04	.08
Musical Corsi	-.04	.29	.17
Day-Night	.03	.43*	.02
Dragon & Lion	-.10	.19	.18
Shape Sorting	.16	.19	-.06
DCCS	-.06	-.16	.02

Note: $*p < .05$

Specific Aim 3 Discussion

Although very few of the correlations reported for this aim reached statistical significance, in a sense these findings are largely unsurprising. Researchers debate the extent to which laboratory-based assessments and parent-reported surveys rarely truly measure the same constructs (e.g. Seifer, Sameroff, Barrett, & Krafchuk, 1994), however very few empirical studies have directly compared these methods of measurement (Garstein & Marmion, 2008; Leerkes, & Crockenberg, 2003). Of note from these analyses is the relation between 42-month Shape Sorting and many of the subscales of the Behavior Rating Inventory of Executive Function – Preschool version (BRIEF-P) at 42 months. Looking at the distribution of Shape Sorting data, it is clear that most children were able to complete this task without difficulty or error, resulting in a restriction of range. Since this particular task was evidently quite simple for most 42-month-olds (most did not make any errors), it stands to reason that of the any children who did struggle would likely also exhibit difficulties that would be noted by a parent.

Interestingly, the other significant relation found was between performance on the Dimension Change Card Sort (DCCS) and the inhibit subscale of the BRIEF-P. Although the DCCS is primarily used as a measure of set shifting, it has also been described as a measure of inhibitory control (Kirkham, Cruess, & Diamond, 2003). Further, as discussed previously, research suggests that set shifting emerges from functional working memory and response inhibition.

Unfortunately, in the 42-month battery, the pairs of tasks that were supposed to be measuring the same constructs did not correlate. There are a number of possibilities for why we found these results, but the lack of relation prevented us from creating composites for the three constructs. Had we been able to use multiple measures for each underlying construct, it is possible that we may have found stronger links between time points and between laboratory tasks and parent-reported executive function.

Another limitation of the analyses in this specific aim is the relatively small sample size of repeat laboratory participants. Although we made every effort during the recruitment process to have as many children as possible from the 30-month visit come back at 42 months, this proved more difficult than expected. Nonetheless, larger samples are likely necessary in order to establish clearer relations between parent-report and laboratory-based measures of executive function, both cross-sectionally and longitudinally.

Chapter 7. General Discussion

The goal of this study was to explore the influence of early attentional behaviors on the development of attentional skills and executive function across the toddler and early childhood years. To answer my research questions, data from both parent-report online surveys and laboratory visits with children were analyzed. Although much of the laboratory-based data failed to show significant findings, the survey data yielded interesting results and provided the opportunity to explore patterns of cognitive development in early childhood.

Specific Aim 1 investigated the relation between 12-month attentional behaviors on the change in attentional and executive control between 30 and 42 months. Four trajectories of change were established based on scores obtained from parent report measures at both 30 and 42 months: (1) good-good (low scores at both time points); (2) good-poor (low score initially but then an increase); (3) poor-good (high score initially but then a decrease); and (4) poor-poor (high scores at both time points). These four subgroups represent four distinct patterns of development, and the analyses revealed that across cognitive constructs, the subgroups differed on scores of attentional behaviors at 12 months. Subgroups formed on the basis of contrasting patterns of performance as judged by ratings on the attentional control, focused attention, and social engagement scales of the Behavioral Dimensions Questionnaire (BDQ) had significantly different 12-month attentional behaviors. Whereas the exact nature of group comparisons varied across outcomes, a composite attention score from the First Year Inventory (FYI) significantly differed between at least two of the subgroups of each scale. Additionally, subgroups from the impulsivity and attentional focusing subscales of the Early Childhood Behavior Questionnaire/Childhood Behavior Questionnaire (ECBQ/CBQ) revealed similar patterns, with 12-month attention differing between groups.

The distinct change patterns across the four groups formed on the basis of variables from the BDQ and the ECBQ/CBQ were related to differences in 12-month attentional behaviors as reported by the FYI. Children in group 1 (good-good) were consistently reported as having better attentional behaviors at 12 months, whereas those in group 4 (poor-poor) had poor attentional behaviors at 12 months. Groups 2 (good-poor) and 3 (poor-good) were differentially related to reported 12-month attentional behaviors, depending on the outcome variable. These results demonstrate that while some parent-reported behaviors remain relatively stable, others improve or worsen, and the nature of change can be linked to behaviors reported at 12 months.

The results of Specific Aim 1 suggest that it is important to move beyond data at a single time point data when studying development. Looking only at data at 30 or 42 months would have resulted in a substantial loss of information about individual, specifically their patterns of development. Thus for Specific Aim 2, data were approached from the same perspective, exploring the relation between 12-month attentional behaviors and 42-month executive function as it differs across the subgroups defined in SA1. Results from these analyses suggest that, generally, there is only a strong relation between 12-month attentional behaviors and 42-month executive function for children whose parents reported good attentional and executive control at both time points. Interestingly, there are children who fall into this subgroup (group 1 – good, good) who have poor parent-reported behaviors in regards to 12-month attention and 42-month executive function. Typically, one of the limitations of parent-report data is that parents may tend to rate their children consistently high or consistently low, so comparisons between children can be challenging. In this case, however, it appears that the potential consistency confound does not necessarily apply, given that both FYI (12 months) and BRIEF-P (42 months) scores were both poor and attentional and executive control scores at both 30 and 42 months from the BDQ and ECBQ/CBQ were good.

The findings obtained in exploring the first two Aims support approaching longitudinal data from an individual differences perspective, as opposed to looking at overall sample patterns. Particularly when studying the behavior of toddlers and young children, it is important to recognize that there is still extensive development occurring across domains. Thus, data from one time point are unlikely to represent a clear picture of the full range of individual variation in a construct of interest. Data collected at multiple time points have the potential to provide interesting information about development, but care should be taken to approach the data from different analytical perspectives (e.g. group vs individual differences).

The goal of Specific Aim 3 was to compare two modes of data collection: parent report and laboratory assessment. Although both attempted to capture aspects of executive function are captured with both methodologies, the findings revealed very few associations among the measures. Although limitations exist for both methods of data collection, the absence of significant findings is still informative. One possibility is that failure to obtain linkages may suggest that these two methods are not measuring the same underlying construct. More research is needed to determine the best way to consistently measure executive function across multiple levels of measurement and to ensure that these different modes are indeed tapping the same cognitive constructs. Consistency across measures would allow researchers to better study patterns of early development.

Developmental Considerations

One of the primary goals of this study was to examine patterns of development in toddlerhood and early childhood. Developmental researchers aim to understand how and why changes occur over time, a goal that differs substantially from that of merely comparing behaviors at two different ages, though comparisons are often the starting point. The results of this study, specifically Aim 1, clearly illustrate the importance of assessing how development occurs across individuals. If we were to simply compare behaviors at 30 months to behaviors at 42 months across the entire study sample, we would see many correlations and predictive relations, given that the variables measured all revolve around the domain of cognitive development. However, when the sample is broken down into different subgroups based on early patterns of development, we find dramatically different results. Although both of these approaches are ways of looking at development, due the longitudinal design, looking more closely at individual differences revealed more detailed patterns of development.

The results of Specific Aim 1 show that 12-month attentional behaviors are predictive of different patterns of development of attentional and executive control across toddlerhood and early childhood. These findings suggest that ratings of behaviors reported at 12 months inform not only distinct behaviors at later time points but also patterns of change. These implications point to the potential utility of measures such as the FYI to better predict how children will develop. To complement these findings, the findings obtained in exploring Specific Aim 2 point to the value in considering these patterns as they relate to the development of higher-order cognition, such as executive function. Given the variability in patterns of development and the subsequent moderating role these trajectories play in the relation between 12-month attentional behaviors and 42-month executive function, developmental scientists should make the effort to look more closely at individual patterns. Age-related differences in cognitive constructs are important to understand, but in order to truly study development, it is important to dig deeper into what leads to these differences and how they arise.

Neurological Considerations

A current emphasis in developmental science is the consideration of multiple levels of analysis. One of the goals of the field moving forward is to integrate the research on behavior with brain structure and function. During the toddlerhood and early childhood years, there is still a high level of plasticity in the brain. Significant changes are occurring throughout the brain, especially in connectivity between different regions and in the development of frontal areas responsible for higher-order cognition such as executive function. Although multiple models could be used to consider the findings obtained here from a neuroscience perspective, only the attention network model of Posner and Petersen (1989) seems particularly appropriate and will be discussed here. This model, as opposed to others such as the the default mode network model (Raichle et al., 2001) or the "salience network" related to insula activation (Menon & Uddin, 2010), was chosen based on its emphasis on aspects of attention and the nature of cognitive control. Further, this model has been studied and used extensively for decades and has more recently been supported by neuroimaging technology (Petersen & Posner, 2012; Posner & Rothbart, 2007). Researchers have replicated and validated the attention network model, focusing on its implications for both typical and atypical neural and cognitive development (Atkinson & Braddick, 2012; Keehn, Müller, & Townsend, 2013; Mundy, Fox, & Card, 2003; Mundy et al., 2007; Mundy & Newell, 2007). Although measures of the neurological correlates of attention or executive function were not obtained in this investigation, it is important to recognize the underlying networks associated with the development of these cognitive abilities.

According to Posner and Petersen (1989), the first network to develop is the *alerting* network, which allows for sensitivity to incoming environmental stimuli and is said to be primed for novelty detection. The alerting network controls the early attentional capabilities of infants that are relied on by researchers when they make use of habituation and familiarization paradigms.

From the perspective of Posner and Petersen, the *orienting* network, is responsible for selective attention develops next, and this network is thought to enable the brain to filter information and respond to certain stimuli, while ignoring others. In addition, the orienting network is thought to control both voluntary and reflexive attentional disengagement and shifting, overlapping in many areas with the alerting network. The orienting network has been described as functionally mature between the ages of 3 and 6 months (Cuevas & Bell, 2013), but is thought to increase in efficiency even into middle childhood. The development of this network has also been associated with the loss of "obligatory looking" (Stechler & Latz, 1966), an important step in the maturation of attentional abilities, and allows for more voluntary control of attention. Moreover, the orienting network is related to the onset of joint attention capabilities, beginning with gaze following. The ability of an infant to detect and follow the gaze of another individual is directly linked to the development of disengaging and shifting attention. The orienting network has been further implicated in the development of imitation or behaviors associated with the perception of the eye and head orientation of others.

The *executive attention* network is the last network to develop and begins to emerge later in the first year with continued development throughout toddlerhood and into early and middle childhood. This network is commonly associated with higher-order cognitive skills such as executive function and attentional control. As it develops, the executive attention network is thought to assume the responsibility of maintaining more intentional sustained attention, observed when toddlers are able to select and maintain focused attention on a particular stimulus when these behaviors are necessary. During late toddlerhood and through the preschool period, more focused attention and less distractibility and fewer shifts of attention are associated with more mature cognitive processing. It is also during this point in development that the inability to maintain focused attention and a lack of attentional control are considered detrimental, with severe deficits pointing to a likely diagnosis of Attention-Deficit/Hyperactivity Disorder (ADHD).

Research suggests that attentional control is first maintained by the orienting network, but that by late toddlerhood this control shifts to the executive attention network (Rothbart, Sheese, Rueda, & Posner, 2011). These areas interact to allow individuals to respond more effectively to increasingly complex situations, such as those that elicit initiating joint attention (IJA) behaviors. In fact, joint attention abilities (responding to and initiating joint attention) have been almost directly mapped onto the attention networks, with the timeline of these behaviors reflecting the developmental trajectory of associated areas of the brain (Mundy & Newell, 2007).

From the perspective of the attention network model, across the toddlerhood years as the prefrontal cortex continues to develop, attentional control shifts from being maintained by the orienting network to the executive attention network as the prefrontal cortex continues to develop. In considering the results of Specific Aim 1 in the framework of the attention network model, it is possible that children with high 30- <u>and</u> 42-month attentional control scores (group 1) may have already made the shift to the executive attention network, whereas those with poor attentional control at one or both time points may still be using the orienting network, or be in the process of transitioning to the executive attention network. Therefore, if a child has poor attention skills at 12 months, the impact of these behaviors on later cognitive development should depend on the ways in which his or her brain exerts attentional control during toddlerhood. As seen in the Specific Aim 2 findings, even with good attentional control, the foundation for potential deficits already exists, such as in those children in group 1 (good attentional control or impulsivity at both 30 and 42 months) who were reported to have poor 12-month attentional behaviors and poor 42-month executive function. However, with poor attentional control, it could be that the underlying networks still need to "catch up," and may do so around the time between 30 and 42 months and after. These factors may contribute to why we see little to no relation between 12-month attention and 42-month EF in these three groups (groups 2, 3, and 4).

Although no neuroimaging data were used in this study, it is useful to consider findings from this perspective. As developmental science moves forward and continues to integrate multiple levels of analyses, findings from each level should be discussed in relation to each other. Ultimately, it would be most beneficial to obtain data from each of these levels, and such findings could then be directly compared.

Psychopathological Considerations

A main reason for initially creating attention constructs from the First Year Inventory (FYI) was the current push for dimensional approaches to understanding typical and atypical behaviors (Stephens et al., under review). Our rescoring and redistribution of FYI items into continuous variables representing a range of attentional behaviors may spark increasing use of the measure and a different approach (as opposed to risk scores) for looking for early behaviors indicative of risk for psychopathology.

As discussed in the Introduction, deficits in aspects of attention and executive function have been linked to psychopathology, and research on these constructs in samples of individuals with autism spectrum disorder (ASD) is especially prevalent, although similar deficits have been found in populations diagnosed with other neurodevelopmental disorders. There remains a strong emphasis on establishing means of identifying risk for these disorders as early as possible, so as to be able to devise and implement appropriate intervention strategies that are tailored to the nature of the impairments (Dawson & Osterling, 1997; Reznick et al., 2007). Although the attention constructs from the FYI provide a good starting point for identifying early deficits, additional research examining the longitudinal correlates of these constructs is essential in determining their clinical applicability.

In the database of children whose parents completed online surveys at both time points, there are two children with diagnoses of ASD. Although the size of this group does not permit in depth analysis or provide conclusive, generalizable results, examining the attentional and executive control subgroup patterns within this sample is a starting point. Although these two children were diagnosed with ASD prior to 42 months, that neither of them was flagged as being "at risk" by the FYI, and their scores on the FYI attention composite were lower (better) than the median. One of the two children fell into group 4 (poor-poor) for BDQ focused attention and social engagement, ECBQ/CBQ attentional focusing and impulsivity, and SRS-2.0. The only variable for which this child was not placed in group 4 was BDQ attentional control, where he or she was in group 2 (good-poor). The second child diagnosed with ASD was in group 4 (poor-poor) for BDQ attentional control and social engagement, as well as SRS-2.0 score. This child fell into group 2 (good-poor) for BDQ focused attention and ECBQ/CBQ impulsivity, and was in group 1 (good-good) for attentional focusing. Although there are many other children in each of the subgroups who do not have diagnoses, it is interesting to note that both of these children, across most of the variables, were in subgroups that either worsened over time or had poor attentional and executive control behaviors throughout. As stated previously, examination of only two individuals by no means provides conclusive clinical support of the subgroups created in this study, but it provides a different perspective from which to look at these children's data, especially given the low FYI attention composite score and risk scores below the set cut-points for risk.

Given the increasing amount of research focused on the developmental trajectories of individuals with ASD and other neurodevelopmental disorders, researchers are recognizing the importance of studying the varying patterns of early change as opposed to single measures at one time point. As discussed in the Introduction, these trajectories may have implications for long-term developmental outcomes, so gaining an understanding of these patterns in toddlerhood may be a key factor in developing appropriate intervention strategies.

Aside from the literature discussing trajectories of individuals with ASD or other neurodevelopmental disorders, there exists little research literature examining impairments in specific cognitive functions that may not be consistent with a clinical diagnosis but may nonetheless have significant long-term influences on functioning and achievement. Taking a more developmental approach to understanding early cognitive development, such as represented in the approach taken here, could help researchers better understand how and when deficits may arise and help lead the way to the best means of addressing them.

Study Limitations

As mentioned above in the discussions of each of the Specific Aims, a primary limitation of this study is the reliance on parent-report data. Although this mode of data collection yielded a relatively large sample with which to conduct a range of primary and exploratory analyses, concerns regarding parent-reported information are documented (Garstein & Marmion, 2008; Leerkes & Crockenberg, 2003). Specific to the FYI attention constructs, there are many assumptions that have to be made whenever infant attentional behaviors are measured (regardless of the method of measurement). As discussed in the Introduction, attentional behaviors during infancy involve a number of cognitive processes that are difficult to disentangle without accompanying physiological measures. Parents' reports of their children's attentional behaviors are thus possibly even more susceptible to errors in assumption and measurement.

Additionally, in the exploration of Specific Aim 3, parent-reported executive function behaviors and laboratory assessments were directly compared. Theoretically, these measures should have been tapping into the same underlying constructs, but the comparisons revealed almost no relations between the two modes of measurement. Just as there are limits to parent report measures, a range of potential problems also exists with laboratory assessments. For example, our assessments took place during one visit, and it is thus difficult to determine if a child's performance was indicative of his or her typical behaviors. Also, children may have behaved differently in the presence of a research assistant than they typically do around their parents. In addition, there were also very few relations between the same measures across time points. Even though this may point to problems with the measures, it also may be reflective of general cognitive development between the two visits, such that the same task may have been completed differently by the same child at each assessment. Additional research is needed to determine why such results were found. It may be that the parent report surveys and laboratory assessments may not be probing the same underlying cognitive constructs, suggesting that future research should explore systematic contrasts in methodology in an attempt to address these questions.

Another limitation stems from the homogeneity of the sample. The majority of the sample was Caucasian, well-educated, and reported relatively high household incomes. A number of factors may have contributed to this. First, the database of parent names that we used for recruitment included only those individuals who had not only previously completed the First Year Inventory but had also agreed to be contacted for subsequent research. Second, there were a number of individuals in the database with incorrect information or whom we were never able to contact. It is possible that although we had a very low rate of actual refusal, these factors may have resulted in a less-representative sample. Although this limits the generalizability of findings to a wider population, the results still support a novel way of exploring early development.

Future Directions

Although the results of this study provided an interesting look into early patterns of cognitive development, further research should extend to include additional measures of both predictors and long-term developmental outcomes related to patterns. As discussed in the Introduction, there has recently been a surge in research linking early executive function to school readiness and achievement in school (Willoughby et al., 2016). However, before significant claims can be made regarding these links, a stronger base of research needs to be established concerning the timing and nature of early executive function. This includes a better understanding of the antecedents as well as the consequences of varying patterns of executive and attentional control in early childhood.

Additionally, future research should explore these developmental patterns in relation to the development and increased functionality of specific brain networks and areas associated with attentional and executive control. Neuroimaging research with toddlers and young children has its own set of limitations, but with appropriate methodology, the next step is to work towards finding links between the brain and behavior. Although the results in this study were discussed in the context of neurological development, until neuroimaging methods are utilized, we are only making assumptions about these relations.

Lastly, the results of this study have implications for early intervention programs. The children for whom we have data in this study represent a wide range of typical and atypical development. Although we did not have access to the children who scored at the highest levels of risk on the FYI, there were two children in our sample who had been diagnosed with ASD. Looking at 12-month behaviors alone and in combination with how they predict patterns of development could inform research on what interventions may be useful in altering impaired trajectories that appear to be related to future risk. This could be done by determining patterns of development that are particularly detrimental for long-term impairment and which cognitive abilities are implicated, and then by tailoring interventions to specifically address these deficits.

Conclusions

This study contributes to our understanding of the importance of early attentional behaviors and patterns of attentional and executive control in the development of higher-order cognitive abilities. By utilizing a longitudinal design along with laboratory and parent-report methods, this study provides a unique perspective on early cognitive development. The findings reported here have the potential to inform not only additional research on specific attentional and executive function behaviors studied here, but also to guide interventions for children who show cognitive impairments at early ages.

APPENDIX

Table 1: Distribution of items in FYI attention constructs

New FYI Constructs		
Responding to Attentional Coordination (RAC) α = 0.729	Initiating Attentional Coordination (IAC) α = 0.747	Sensory and Attentional Engagement (SAE) α = 0.786
1. Looks when name is called	7. Looks at your face for comfort	13. Rocks body back and forth
4. Excited when knows what will happen next	19. Tries to get your attention to show things	17. Presses against things
10. Turns to look at pointed out object	20. Tries to get your attention for interactive games	30. Repeats simple activity over and over
12. Looks at people when they talk	21. Tries to get your attention to obtain a toy	33. Enjoys staring at bright lights
14. Looks up from play when shown new toy	22. Tries to get your attention for physical games	37. Gets stuck on playing with a part of a toy
24. Imitates mouth sounds	29. Tries to get attention by sound and gaze	42. Enjoys rubbing or scratching objects
25. Imitates body movements	34. Uses communicative gestures	44. Enjoys making objects spin over and over
26. Imitates activities with objects	38. Uses finger to point at things	45. Enjoys kicking feet over and over
35. Responds to “Where’s ____?”		46. Stares at fingers while wiggling them
49. When you introduce your baby to a new game, how he/she responds		47. Your baby’s typical play with a favorite toy
50. What you have to do to get your baby to look up from playing with a favorite toy		48. Your baby’s interest in toys on a typical day
52. What you have to do to get your baby to turn towards you		59. Does baby keep a toy or object in his/her mouth
53. What you have to do to get your baby to smile or laugh at you		
58. What baby typically does when you start a game by imitating		

Table 2. Results of phone calls to potential participants

	30-month wave	42-month wave
Recruited and completed all surveys	313	382
Recruited and completed partial surveys	34	96
Recruited but did not complete survey	174	113
Refused	50	33
Unable to contact or speak directly with parent*	266	104
Wrong number	123	53

Notes: *These numbers include parents for whom voicemails were left (only if the message was clear that the correct person had been reached) and those with whom no contact was ever made (no voicemail left)

Table 3. Summary of recruited laboratory participants

	30-month wave	42-month wave
Visited and provided usable data	76	108
Recruited but no-show	6	3
Recruited but canceled	23	10
Practice participants	17	9

Table 4: Distribution of items in Behavioral Dimensions Questionnaire (BDQ) constructs

BDQ Constructs		
Focused Attention α = 0.759	Attentional Control α = 0.707	Social Engagement α = 0.729
1. Listens	5. highly distractible/easily startled/attention to changes interferes with activity	4. speaks up/off topic
3. Enthusiastically engaged	7. needs to be asked/told what to do several times	12. initiates conversations/interactions
6. Acknowledges questions/comments, but returns to own activity	9. not restless, but moving; floats and engages briefly	13. repeatedly tries to interact with other children/adults when they're busy
8. Shows sustained interest and engagement for 20 minutes	16. needs help to stay on task	20. annoys/disrupts others when busy
10. Attends with eyes and ears when taught something new	18. spacey, out of it, not really attending	26. takes turns in conversation; able to stay on topic
14. Persistent, goal-directed behavior	24. driven to find one thing/person, do one activity, even when encouraged to change activity	27. interrupts adults when busy
17. Focused concentration	25. starts to respond when told to get/do something, seems to forget goal	30. rejects/ignores overtures from others; unwilling to change
19. Shows sustained interest and engagement for 10 minutes		
28. Shows sustained interest and engagement for 5 minutes		

Note: Data for the Cronbach's *alphas* reported here are from the 30-month wave of data collection only.

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